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A HOBGOBLIN OF THE SPIDER CLAN

A BIRD-EATING SPIDER OF THE WEST INDIES

The Book of
POPULAR SCIENCE

The Wonders of Modern Discovery
The Triumphs of Inventive Genius
The Story of all Created Things and
the World They Live In

EDITED BY

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VOLUME
XIV

THE GROLIER SOCIETY
Publishers of The Book of Knowledge
NEW YORK

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SUN-CLUSTERS AND NEBULÆ

Various Aggregations of Celestial Lights, from Star-Groups to a Feebly Luminous Nebular Fog

THE GORGEOUS DIADEM OF THE PLEIADES

WE have seen that double stars, or systems of two stars physically related to one another, are extremely common in the heavens; and, further, that with improved means of observation these binary systems tend to reveal a more and more complex nature. Systems of three, four or more stars, variously related, are known to exist, and some progress has been made in discovering the nature of their relations. But these small systems hardly prepare us for the astounding phenomena of star-clusters, which appear like supreme works of celestial jewelry.

The familiar acquaintance with the night sky, which country people have from childhood, accustoms the mind to the idea of large numbers of stars grouped together with architectural design in the constellations, and presumably related to one another by some physical bond. It is true that a very little learning is enough to show that this impression is largely erroneous, and that the grouping of the stars in constellations is principally no more than the optical effect of perspective. But the progress of astronomy is always finding actual relations between celestial bodies; and when the lay mind takes for granted that the stars of the Great Bear or of Orion are obviously related to one another, it is instinctively scientific, because it derives its sense of physical union from the evidence of formal design. The argument from formal design is, in fact, one of the chief evidences which astronomers bring forward when they assert a real physical relation between the members of a star-cluster or group.

The most famous of all star-clusters has been known and honored from the earliest days. The Pleiades are perhaps the most illustrious of all heavenly systems; many primitive peoples have felt that they had some profound concern in the affairs of human life; and the phases of their rising and setting have been accepted as a calendar by toilers of the land and of the sea. And now the members of this vast group have been proved to be related in a real systemic union, by their possession of a common proper motion. It is probably only an apparent motion, due to our own sun's journey through space, but is no less convincing on that account, since it is found to be the same for all the members of the group. Their mutual positions maintain complete rigidity, showing that, as one moves, so do all the rest.

They form, indeed, a most marvelous and majestic group. Their distance from us is believed to be at least two hundred and fifty light-years and it may be as much as four hundred light years; yet even at this enormous distance the chief star, Alcyone, appears of the third magnitude — a fact which proves it to be some two hundred times more powerful as a luminary than our sun. Sirius itself, being only forty-eight times as bright as our sun, would come but seventh in respect to brilliancy among the chief stars of the Pleiades, if it were situated among them. The principal stars of the group, six in number, are Alcyone, Electra, Atlas, Maia, Merope and Taygeta, all of which are of the fifth magnitude or brighter. The general form of the group, as seen by unaided vision, is well known, and is due to

the positions of these six stars, Alcyone occupying a central position, though probably not really exercising a dominant influence on the rest of the group.

The gorgeous diadem of resplendent suns forming the Pleiades

The number of stars actually belonging to the system of the Pleiades is at present undetermined. Over two thousand three hundred, down to the sixteenth magnitude, were counted in their vicinity in 1887, and four thousand stars appeared on a photograph of the region taken ten years later. But it is almost certain that only the most brilliant actually belong to the group. Most of the small stars appearing within its area are known, by the absence of proper motion, to be only visually connected with it, and to be actually at immense distances beyond it in space. Some of its brighter stars, on the other hand, have proved to be much nearer to us than the Pleiades; they display a proper motion in excess of that which is characteristic of the group, and are therefore known to be crossing the plane of vision between us and the Pleiades. But at least forty-five of the stars which have been specially studied are known to be true members of the group. These, with perhaps many smaller stars not yet determined, and having Alcyone in their center, move together through the heavens, probably pursuing at the same time many and various mutual revolutions among themselves, forming subordinate systems within this gorgeous diadem of resplendent suns.

The nebulous material in which the Pleiades are embedded

Yet the spatial extent of the Pleiades is so vast, and their distances from one another so great, that even Alcyone, with its two-hundred-sun-power of brilliancy, only reaches the nearest of its great companions as a supremely bright star, some eighty or ninety times as brilliant as Sirius appears to us, and with a power almost sixty-seven thousand times less than that with which our sun reaches the distant orb of Neptune. So vast is this imposing system, so unimaginable its measurements.

Still, the Pleiades are near enough to afford us much very valuable information, not only with regard to star systems, but also concerning the relations between stars and nebulæ. The whole group is, as it were, embedded in enfolding nebulous stuff. Wisps, tails and clouds of nebulous material are apparently attached to various stars of the group, especially to Merope, around which they lie in bars, for the most part parallel with one another; to Maia, in a spiral form; to Electra, in a straight pointed bar directed toward Alcyone; and thickly rolled round Alcyone itself in fog-like clouds. But the nebula is much more comprehensive than these outstanding features would suggest. It involves not only the Pleiades, but a vast region around them on all sides. Several peculiarly interesting discoveries in regard to nebulæ and stars in general have been made in studying it. For instance, several long threads or ribbons of the luminous cloud-stuff are seen to string together lines of individual stars, uniting them like beads on a string. This seems to prove that lines of stars are really connected, and not fortuitously placed in their rectilinear position. Lines of this kind, either straight, arched or in beautiful regular loops and festoons, are common features of many clusters; and it had become evident to observers that these arrangements must be the result of real relations, before that opinion was finally established by the nebulous connecting lines in the Pleiades.

The bridging of the gap between open star-clusters and diffuse nebulæ

Clusters such as the Pleiades, in which a group of stars physically related in a single system is combined with a nebula, seem to bridge the gap between star-clusters and nebulæ. The stars in these clusters have, so far as they have been examined, been found to be of the "Orion" type, and have long been regarded as having newly arisen from the "shining world-stuff" in which they are still involved. Many astronomers, however, are now inclined to the opinion that the nebulous envelope is being formed by the expulsion of tenuous matter from the stars.

The forms of star-clusters are often exceedingly beautiful and interesting. Lines, either straight or forming loops, arches, streamers or more complicated figures, are traceable in many; a considerable number take the form of a half-open fan; others show by their names the resemblances suggested by their shapes. Thus, we have Præsepe, the "manger", which appears as a feeble cloud of light between two stars both of the fourth magnitude. These two stars were called by early astronomers the "asses". Globular clusters are in many ways distinct from the rest, chiefly by their regularity of form and the usual absence of any real nebulosity. We shall consider them later. Colored stars are sometimes present, and in some cases various colors combined give great splendor and beauty to a cluster, as in a famous group in the Southern Cross.

Frequently a bright-colored star occupies a conspicuous and dominating position in a cluster of undistinguished stars, as in certain clusters which occur in Auriga and in Cygnus. Double stars occupy a central position in a cluster in Perseus. In Gemini is found a cluster containing within it a small, clearly defined cluster of seven or eight stars very close together. In Auriga there is a cluster in the form of a cross; on each arm there are two particularly bright stars, distinguished above all the rest. Similar devices of symmetry or effective placing are frequent. Well-defined geometrical forms, such as triangles and rectangles, are by no means uncommon.

Globular clusters are in general much more sharply defined than are the various irregular forms considered above. Occasionally the edges of the globe are clean and entire, but more often they are radiated by outward streamers and thread-like appendages, suggestive of an outward flow from the cluster, as if it might be a nest of bright new suns to be sent out gradually to occupy the spaces of the heavens. This may, in fact, be in some sense a true account of them, but it is certainly too early in the history of their observation to allow of any definite theory of this kind. The number of stars in globular clusters varies considerably, but a cluster usually contains many thousands of stars, in some cases

A PHOTOGRAPH OF A REGION IN THE PLEIADES, SHOWING ITS NEBULOUS CHARACTER

hundreds of thousands, and it is estimated by Dr. Harlow Shapley, from his study of many star-clusters made at Mount Wilson, that on the average the combined light of a cluster is about two hundred and seventy-five thousandths that of the sun.

The grouping of star-clusters in symmetrical arrangements

Very beautiful indeed are these wonderful balls of suns when seen in a great telescope. One of the most perfect is found in Centaurus, where it appears to the naked eye as a rather blurred fourth-magnitude star. In a good telescope this star becomes transformed into a vast sphere of brilliant, glorious suns, of which over five thousand have been counted by photographic means.

A similar but smaller cluster in Tucana is even more closely packed with bright suns, over two thousand being grouped within a boundary line of comparatively small radius. Another famous example is the globular cluster in Hercules, with over thirty thousand stars brighter than our sun, besides many times more than that number which are less brilliant; this cluster sends out streamers and tentacles of stars to a distance which nearly doubles its diameter. In all these clusters the thickness of the crowding of stars increases in regular progression from circumference to center. The Hercules cluster is broken, as it were, by three dark rifts or lanes leading outward from a point not at the center, but to the southeast of it. The dark lines are found, however, from photographs of longer exposure, one of which is shown on page 4773, to be not really devoid of stars. They are strewn with small, faint stars, as, indeed, is the whole cluster, these small, faint stars being disposed apparently in really globular order. But there are also many bright stars, disposed in radial lines stretching outward in curves; and these are entirely absent from the dark lanes, which no doubt appear dark partly by contrast.

The stars in a globular cluster are usually graded according to brilliancy in an extremely methodical way. The arrangement of smaller stars in the center, with bright ones scattered over them, which we can trace in the Hercules cluster, prevails also in most, if not all, others.

The number of variable stars found in globular clusters is very remarkable, and as yet not understood. As many as a hundred have been found in a space in the sky that would be covered by a pin's head held as far away from the eye as it could be distinctly seen.

The Centaurus cluster is an example which is fertile in variables. Out of three thousand examined by Bailey of Harvard, nearly one hundred and thirty were found to be variable, for the most part within one and a half or two magnitudes, and sometimes less, down to an extent of half a magnitude; sometimes more, up to one which varied to the extent of five magnitudes. There seems to be no interdependence in the changes of the various stars in a cluster. Each varies apparently on its own account, as if entirely unrelated to its fellows. Miss Clerke thus comments on this extraordinary phenomenon:

The strange waxing and waning of stars in star-clusters

"No more curious spectacle is afforded by the heavens than that of a throng of seeming signal-lights waxing and waning every few hours under the sway, obviously, of some common law, yet with no trace of unanimity, some fading while their neighbors are on the rise, others stationary and semi-extinct, though only biding their time to enter upon a phase of renewed brilliancy, and none deviating by a hair's-breadth from the course of change individually prescribed for it."

The Hercules cluster is much more stable in light than the majority of globular clusters. But, on the whole, variability is a common feature of cluster stars. It is of a special type, consisting in long quiescent periods of comparative dullness, with short and quickly attained periods of brilliancy, the whole recurrent period being usually very short, and often measured in hours. For example, eighty-five variables have been discovered in a very fine cluster in Libra, almost all of which have a period of about twelve hours, although without

any apparent order in the times of occurrence. No physical differences, so far as can be ascertained, distinguish clusters rich in variables from those whose stars shine steadily.

The variation in the appearance of star-clusters determined largely by distance

The stars composing the various clusters are no doubt of different sizes, and are packed with different degrees of closeness. But at least a part, and probably a considerable part, of the differences which make one cluster resemble a heap of fine sand, while another cluster resembles a heap of much larger particles, is due to a difference of distance from the earth. For the same reason it is probable that many very distant clusters escape recognition, because they present the appearance of nebulæ.

We have already referred to the relations between open star-clusters and diffuse nebulæ. These two kinds of structure, as may be seen in the case of the Pleiades and of hundreds of other irregular clusters, are very frequently found together, merged in one another and united in a manner which leaves little doubt that nebulæ condense into stars or else that stars disintegrate into nebulæ.

The puzzling problem of the relationship between nebulæ and stars

The study of nebulæ is most fascinating, and is likely to prove very illuminating. It is remarkable that almost all forms and conditions of stellar existence have their close parallels in nebular existence, though of course in a vague and shadowy manner. Thus we have nebulous stars and planetary nebulæ, double nebulæ answering to double stars, variable nebulæ and there are even two great classes of elliptical and irregular nebulæ, corresponding to the globular and irregular forms of star-clusters.

Nebulæ abound in the heavens, and assume all kinds of odd and beautiful forms. There are tails, brushes, wisps, rings, fans, rays, triangles, squares, discs, spheres and many other shapes, but almost all hidden from unaided vision. The only one which is easily discernible is the great nebula in Andromeda (see pages 35 and 458).

The most easily seen and historical nebulæ in Andromeda

This is the supreme example, as far as apparent size and visibility are concerned, of the regular or elliptical form of nebula, and was well known to Al Sufi, the Arabian astronomer, in the tenth century. Nebulæ of this form were called by Professor Young "white nebulæ", as distinguished from gaseous nebulæ, such as the great irregular nebula in Orion (see page 459) and others of similar type. White nebulæ give a continuous spectrum, and are probably of quite different constitution from gaseous nebulæ. Their forms are usually quite definite, and brighten progressively from circumference to center, often condensing finally in a small nucleus similar to that of a comet. Dark curved bands, following the form of the ellipse, frequently intercept the disc of elliptical nebulæ; and a careful study of these bands, and of the dark lines or rifts in the various white nebulæ, has proved that they are essentially spiral in structure, though the appearance varies according to the inclination at which we see the nebula. A very comprehensive photographic survey of these nebulæ was inaugurated and partially completed by Professor Keeler, with the Crossley telescope of the Lick Observatory; his work was continued by Perrine and others and in almost all the photographs thus obtained the traces of spiral formation were manifest (see pages 28, 33, 1160, 1161).

The clearest and most beautiful of the spiral nebulæ

The various forms which are assumed are often very beautiful. The spiral is often double, two diametrically opposite branches being thrown outward from a central nucleus, sometimes in the direction of a second nucleus which is finally reached by one of the branches. The clearest and most beautiful specimen of this type is a nebula in Canes Venatici, called, from its appearance, the Whirlpool nebula. Two streams of luminous matter proceed from the nucleus at opposite points, and circle about it in spiral form in the direction in which the hands of a clock travel.

Both of these arms are uneven, and full of thick patches and bosses; they divide and again unite; and they give off tails which are turned away from the nucleus, like the tails of comets. One branch dies away to nothing; the other and longer gains a second nucleus at some little distance, after executing a complete curve about the primary nucleus. The whole appearance of the nebula suggests the combined effect of repulsive and rotatory forces, and has striking analogies with the structure of comets. The peculiar clearness of the Whirlpool nebula is due to the fact that to our vision it is scarcely foreshortened at all. In some nebulæ the spiral takes the form of an S, of which a good example is found in Pegasus. In this case, only parts of the complete spiral could be seen by means of the telescope, and various observers gave it very different forms, but its double spiral was revealed as soon as photography was applied.

The theory of kinship between spiral nebulæ and globular clusters

Almost all white nebulæ, with their spiral structure, are more or less globe-like bodies, and the theory that they are related to globular clusters has suggested itself to many observers. They all glow with continuous light. Their spectrum has not yet been satisfactorily interpreted, but it appears to support the theory that white nebulæ are, in fact, star-clusters, situated at such a distance that the light of their individual stars has become merged into a faint haze of soft light. Several difficulties, however, stand in the way of this theory. In the first place, the light is so faint that if the extensive clusters of nebulæ do indeed represent clustered stars, these stars must be at enormous distances apart. Moreover, if the light be due to merged starlight, the stars must be many times farther apart in the fainter regions of the nebula, and in that case the wider scattering should produce a different texture, and the individual stars should become separated to our view. But this never happens. The texture of nebular light appears exactly the same in all grades of brightness. And again, the clusters are almost all in the region of the Milky Way, while the spiral nebulæ are quite absent from this region. The cluster theory of spiral nebulæ is therefore difficult of acceptance.

These nebulæ are very large and very far away, and though it is not possible to determine their distance and size with exactness, recent measurements by Van Maanen at Mount Wilson on the spiral M. 33 in Triangulum give as its distance 6000 light-years and indicate that it has a diameter of about 60 light-years. That the spiral nebulæ, or at least the brighter central portions, are in rotation was proved by the spectroscopic investigations of Slipher and others, and now the measurements of the outlying nebulous condensations made by Van Maanen show clearly by direct evidence that the entire nebula is in rotation; the period for different nebulæ so far observed varies from 50,000 to 200,000 years. This may seem a slow rotation, but it means a very considerable linear speed on the periphery of such enormous bodies.

Gaseous nebulæ are far less numerous than white nebulæ, in the proportion of less than one to a hundred. They are all of irregular shape, of large size and of ill-defined outlines and, unlike the spirals, are found mostly in or near the Milky Way. Only parts of them become apparent to direct vision, even in large telescopes; but the dimmer parts and outer regions impress themselves easily on photographic plates, showing that their light is of far greater actinic than it is of visual power. It may almost be said that each irregular nebula is of a class apart, for they all display strong individual characteristics. Thus, the dominating feature in the great Orion nebula, sometimes called the "Fish-mouth", is a trapezium of bright stars with a bright central region about it.

Features of the great irregular nebulæ, the "Fish-mouth" and "Keyhole"

In the second greatest, the nebula in Argo, known as the "Keyhole", the most prominent feature is a sharply defined black opening, which has given its name to the nebula, gaping right in the center

of its brightest part. The Trifid nebula, in Sagittarius, is dominated by a bright multiple star situated just at the inner edge of one of the three petal-like lobes from which the nebula takes its name.

The most famous and resplendent of irregular nebulæ is undoubtedly the great Fish-mouth in Orion. It may be seen with an opera-glass as a silvery cloud round a multiple star in the sword of Orion. It was first attentively studied by Huygens in 1656, and from him the central bright part forming the so-called Fish-mouth became known as the "Huygenian region".

The part of the heavens named after a Dutch watcher of the skies

One of the stars of Orion is seen, by the aid of the telescope, to be multiple. The four chief component stars which constitute it form a trapezium, which is, as it were, the hub of this whole great nebula. These stars are of the fifth, sixth, seventh and eighth magnitudes respectively, and they are very close to one another.

They are actually embedded in the nebulous matter, as is confirmed by the spectrum of the multiple star, which shows very close nebular affinities. These stars have a small proper motion corresponding, at their computed least distance of a thousand light-years, to a real motion of about fifty miles a second; and it seems certain that the nebula shares this motion.

Photographs of this great nebula are very beautiful and impressive. The Huygenian region forms roughly a right-angled triangle, the base of which is broken to form the mouth of the sky-monster. It is most sharply defined along this edge, but with increasing photographic power this outline, too, becomes softened in vast clouds of fainter and far more extensive nebula. The whole formation has probably by no means been yet revealed, for its boundaries extend further with every new improvement in the instruments of research. It holds a central position in a wide region abounding in nebulæ, and it is likely that these will be found to be connected. At present the limits of the great nebula include a considerable portion of Orion's body. A large curved nebular cloud sweeps round the belt, and the Fish-mouth within it, and already distinct traces of a spiral principle working on an enormous scale have become evident in the whole.

The color of the nebular light is faintly green, and the Fish-mouth has an unearthly appearance when viewed in a good telescope. The mouth is the center of apparent nebulous rays running out from it in all directions, in forms strikingly like the rays of the solar corona; and these effluences go to make up the outer parts of the nebula. The close similarity of form between the corona and the great nebula is rendered the more significant by the fact that hydrogen and helium are found together in the spectrum of both, whereas in starlight, as one of these gases appears, the other regularly disappears from the spectrum.

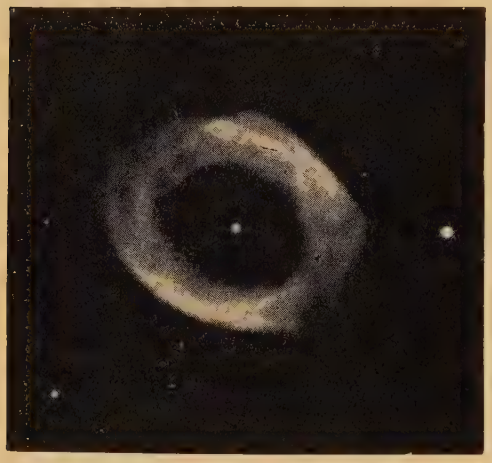
The strange colors of the great irregular nebulæ

All the irregular nebulæ have the same strange, greenish tinge. The Keyhole nebula in Argo, mentioned above, is a magnificent object, following as it does a procession of peculiarly bright and numerous stars. It extends over more than a square degree of the heavens, and more than twelve hundred stars are seen projected upon it. Some of these, if we may judge from the significant positions in which they occur, must be actually situated within the nebula. In the center and very brightest part of the nebula is a black opening in the shape of a keyhole, and exactly upon the edges of this dark cavern are seated four bright stars. No stars whatever can be seen within the keyhole.

It is often not easy to say whether an object should be regarded as a star with filmy appendages or as a nebula with a stellar nucleus. A true nebular star is surrounded by a luminous halo which cannot properly be called an atmosphere, since it is both self-luminous and inordinately extensive. Thus, the halo of the first nebular star to be discovered is of an extent sufficient to fill a space twenty-

seven thousand times greater than that contained within the orbit of Neptune. The stellar nuclei are often compound: one in Auriga consists of three stars set in the form of an equilateral triangle, placed exactly in the center of a small circular nebula. Another in Orion also consists of three stars, respectively yellow, purple and white, embedded in a nebulous halo.

Nebulous stars with compound nuclei are connected by transitional forms with double nebulæ. Increasing instrumental power tends, however, to merge nebulæ, formerly supposed to be double, into single nebulæ; whereas stars formerly supposed to be single are more and more divided



THE ANNULAR NEBULA IN LYRA
From a photograph by G. W. Ritchey

into compound systems by the advance in optical efficiency. Yet the clearly defined double nuclei in the spiral nebula in Canes Venatici, referred to above, and others of similar constitution, lead us to a belief in the real existence of double nebulæ. Sir John Herschel made a special search for these objects, holding that they might represent the early stages of double stars. Compound nebulæ have been found in all combinations similar to those of double stars. Thus, we find a single primary nebula with two satellites; a single satellite attending two primaries; three fairly equal companions; doubles of various forms, such as elliptical, globular, lenticular; and other combinations. A curious example in Pegasus consists of three small nebulæ placed at the angles of a triangle whose sides are sketched by filmy nebulous bands, and in the midst of this figure is a bright double star.

Planetary nebulæ usually appear elliptical in shape, and are probably really spheroids. They contain a stellar nucleus situated apparently within a disc, the latter having a more or less complicated form often suggesting the envelopes in the head of a comet. The largest of planetary nebulæ, known as the Owl, was described by the younger Herschel as "a large, uniform, nebulous disc, quite round, very bright, not sharply defined, but yet very suddenly fading away to darkness". Later, two stars were observed within it, each in the center of a dark cavity, with a bridge of luminosity between them, giving to the whole a singular likeness to the face of an owl. But the stars have since become invisible, being replaced by a single bright star on the central bridge of light, and dominating the whole nebula.

Annular or ring nebulæ are often very beautiful. The most perfect, situated in Lyra, appears as a hoop of filmy light surrounding a star. The hoop is neither even nor circular. It is oval in form, and brightest at the extremities of its shorter axis, fading considerably at the ends of the longer axis. Photography shows the center to be covered with a filmy veil, and it is believed that the ring is the effect of a tenuous globe seen in perspective, through which the central star shines unobscured.

It is expected that knowledge of the nature of nebulæ will be gained principally by the spectroscope. The general results of spectroscopic study have revealed conditions of great rarefaction and of very low temperature. It is also known that nebulæ are of excessive tenuosity, because of their enormous volume, together with their inability to produce large velocities in the stars in their vicinity.

Calculation has shown that the Orion nebula, at the lowest estimate of its size, if composed of matter one million times rarer than our atmosphere, would be capable of producing great velocities in all stars near it. But no sign of any such

effect is found among all the stars of the region; indeed, the stars about Orion are singularly fixed. The density of this nebula must therefore be immeasurably less than that of air in a vacuum tube.

The investigations of the diffuse nebulæ made by E. Hubble at Mount Wilson show that these galactic nebulæ are too cold to be self-luminous in the ordinary way and that they derive their light proved by the long labors of the much lamented Barnard. His observations and photographs of many regions containing these dark nebulæ show that they are diffuse masses, often of enormous volume, consisting probably of cosmic dust or fine particles and obscuring the light of the Milky Way which lies behind them. And more recently Father J. G. Hagen, the Director of the Vatican Observatory, has

INTERNAL MOTIONS OF MESSIER 81 IN 1300 YEARS
From a photograph taken with the 60-inch reflector at Mount Wilson Observatory.

either by reflection or by excitation from the stars involved in them or closely associated with them. These stars are of the very hottest types and produce the nebulous luminosity in a way not yet clearly understood.

Finally must be mentioned that large class of nebulæ which are not seen, namely, the dark nebulæ, the existence of which in large numbers has been so convincingly published a long list of smaller dark nebulæ which are not restricted to the region of the Milky Way but are found in all latitudes even up to the galactic poles. These nebulæ, like those photographed by Barnard in the Milky Way, can be discovered only by the fact that they cut off the light of the more distant stars and thus become known to us not by their light but by their shadows.

WONDERFUL VARIETY OF STALAGMITE AND STALACTITE FORMATIONS

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IN THE BELLAMAR CAVES, MATANZAS, CUBA

IN THE BOWELS OF THE EARTH

The World's Impressive Subterranean Hollowings and Cavernous Waterways

A DUSTLESS AND GERMLESS UNDERWORLD

LET us now consider the subject of caves. Though caves have not the grandeur of waterfalls, they have always appealed to the imagination of men. There is room in their shadowy grottoes for many dreams and many mysteries, for sibyls and nymphs, for fairies and gnomes, for Typhon and Cyclops. From caverns spake the oracles of Corinth and Delphi; into a cavern in a hill did the Pied Piper lead the dancing children; and a cavern in the hills of Granada still hides Boabdil and his Moors. But caves have appealed not only to the imagination, but also to the practical instincts of men; they have been used from time immemorial as dwelling-places, as fortresses, and as tombs. Lot went up from Zoar and dwelt in a cave, he and his two daughters; in caves kings of Canaan and kings of Scotland, freebooters, smugglers and martyrs have found refuge from their foes. In a cave good Obadiah concealed a hundred prophets; in a cave Joshua imprisoned five kings. In the cave of Machpelah sleep Abraham and Sarah, Isaac and Rebecca, Jacob and Leah, and Joseph.

It is probable that whole races of Palæolithic men dwelt in caverns, kindling fires, cooking food, sharpening their flints there and drawing pictures of mammoths and bisons on the cave walls. In Neolithic days multitudes of men inhabited caves, and much of our knowledge of early man is derived from a study of the contents of such rocky chambers. Even now in parts of France, Spain and Italy cave-dwellers are to be found, and in the Canary Islands, within a stone's throw of modern hotels, natives still live in caves.

Burial caves, like dwelling caves, are found all the world over, and, like dwelling caves, have done much to throw light on the ways of primitive man. In the cave of Itruipe, in South America, Humboldt counted 600 skeletons and mummies preserved in baskets woven from the petioles of palm-leaves. Along with the skeletons and mummies were found sandals, implements and ornaments. In burial caves in the Aleutian Islands, Mr. W. H. Dall, paleontologist of the U. S. Geological Survey, found mummies in a sitting posture which had been most carefully wrapped in fine woven grass ornamented with tufts of feathers and reindeer hair, surrounded by a coarser covering and overlaid with a coat made of bird skins. These bundles were again packed in dried grass, covered with large otter skins and made secure with a braided network of twisted sinews. Beside the mummies were found masks and effigies, awls and needles, axes and arrows. In a cave in Teneriffe were found more than a thousand mummies, which had been embalmed, sewn up in goatskins, and bound with leather.

Many caves, known as "bone caves", are notable chiefly for the bones of animals which they contain, and the light they thus throw on the biological history of the country. In a cave in Yorkshire, England, Buckland discovered teeth and bones of no less than twenty-three species of animals — hyena, tiger, bear, fox, weasel, elephant, rhinoceros, hippopotamus, horse, ox, deer, hare, rabbit, water-rat, mouse, raven, pigeon, lark, duck. In the Wookey Hole, near Wells, England, have been found those of grizzly bear, fox, woolly rhinoceros,

great urus, reindeer, cave-lion, brown bear, badger, bison, red deer, cave-bear, wolf, mammoth, horse, Irish elk, lemming and, last but not least, man.

The bone caves of Belgium are particularly rich in animal relics. That at Lunal-Viel, for instance, contains nearly one-half of all the hundred-odd species that have been discovered in caves. In the Gailenreuth Caves, in Franconia, bones of no less than 800 bears were found. In the Neanderthal Cave near Düsseldorf was found the famous so-called "Neanderthal" skull — a human skull of very

THE LAKE AND ITS ISLAND IN WOOKEY HOLE CAVE, NEAR WELLS, ENGLAND

great antiquity. The caves in North America that have yielded animal remains, such as Port Kennedy and Frankstown, Pennsylvania, according to Scott, are hardly caverns in the ordinary sense of the word, rather narrow fissures into which bones and carcasses were washed by floods.

Caves have also preserved for us examples of the dawn of art. In the Pyrenees, the Cave of Murat, lately explored by the Abbé Lemozi, was so rich in pictures and graving tools that it was believed to have been the dwelling place of a family of professional artists of the Stone Age. And quite recently, September, 1923, the same explorer reports a great gallery 340 feet long and 35 feet wide on the walls of which are painted and engraved, in red and black, pictures of forty prehistoric animals.

Caves originate in various ways — they may be volcanic in their origin; they may be excavated by the sea or by subterranean streams and rivers. Volcanic caves may be made in the crust of the earth simply by ejection of lava. In a single eruption a volcano may pour out millions of tons of lava, and, naturally, the ejection of this large amount of material must leave holes in the crust. Or they may be made in the lava itself by the shrinkage of its interior. Such "lava caves" are often of considerable size. There is one near the base of Monte Rossi about a mile long; and Professors Brewer and King explored a lava cave on the flank of Mount Shasta half a mile long, whose sides were dimpled with blister-holes and lined with lava-froth. The finest lava caves in the world are found in Iceland, and the finest of the Icelandic lava caves is the Surtsheller. The tremendous eruption of Skaptar Jökull in

1783 spread a torrent of lava over an area of 420 square miles, and in the center of this enormous mass of lava is the Surtsheller lava cave. The cave is named after Surt, the Prince of Darkness of the Scandinavian mythology. It is entered through a chasm in the lava, and is about a mile in length, and for nearly 4000 feet is 40 feet high and 50 feet wide. Dr. Ebenezer Henderson, who explored the cave first, nearly a hundred years ago, says that: "The roof and sides of the cave were decorated with the most superb volcanic icicles, crystallized in every possible form, many of which rivaled in minuteness of beauty the finest zeolites, while from the floor rose pillars of the same substance, assuming all the curious and fantastic shapes imaginable, mocking the proudest specimens of art and counterfeiting many well-known objects of animated nature. Many of them were upwards of four feet high, generally sharpened at the extremity, and about two feet in thickness. A more brilliant scene never presented itself to the human eye, nor was it easy to divest ourselves of the idea that we actually beheld one of the fairy scenes depicted in Eastern fable."

A SINK-HOLE ENTRANCE TO THE MAMMOTH CAVE, KENTUCKY

Marine caves made by the eroding action of the sea are very numerous. The most typical are made not in soft but in hard rocks, such as basalt. The soft rocks are broken down altogether; but the hard rocks are more resistant, and are eroded chiefly where there happens to be weaker spots in their armor. The high granite cliffs of Sark, one of the Channel Islands, are honeycombed by caves, as are also the rugged coasts of Norway. One of the best specimens of a marine cave is found in Fingal's Cave, on the island of Staffa, off the northwest coast of Scotland. It appealed to Scott as a place

> Where as to shame the temples decked
> By skill of earthly architect
> Nature herself, it seemed, would raise
> A minster to her Maker's praise!
> Not for a meaner use ascend
> Her columns or her arches bend;
> Nor of a theme less solemn tells
> That mighty surge that ebbs and swells,
> And still, between each awful pause,
> From the high vault an answer draws,
> In varied tone, prolonged and high,
> That mocks the organ's melody.

The island of Staffa is a mass of igneous rocks, and around its coasts are grouped immense basaltic pillars. Strong and hard though the pillars be, the sea has eaten into them in places, and hollowed out seven caves. The most remarkable of these is Fingal's Cave. It is 227 feet long, 42 feet broad, and 66 feet high, and 25 feet deep at ebb. The arched entrance is 33 feet wide and 65 feet high. It is not a large cave as caves go, but its boast is its architecture, not its size. Its roof is supported by ranges of great basaltic pillars about two feet in diameter, and having five or six sides, and both roof and floor show sections and stumps of columns that have been broken away by the sea. There is not "a single stone or fragment which is not prismatic, and symmetrically, perfectly and regularly sculptured". Walls and roof, too, are beautifully polished, and reflect in places bright orange and emerald tints, which give varied beauty to the twilight in the interior of the cave. The Celtic name of the cave means "harmonious grotto", for the sea winds and sea waves harp on the great columns and make a low, sweet harmony.

We now come to the most interesting class of caves — those excavated in limestone rock by subterranean water. Any one who has noticed the corrosive effect of the dripping of a siphon of carbonated water upon a marble slab will readily understand how underground water, impregnated as it always is with carbonic acid, must in time corrode caves in the limestone rock. These caves depend for their beauty chiefly on their stalagmites and stalactites, the calcareous growths formed by the limy water dripping from their roofs and walls. The water carrying limestone in solution as the bicarbonate drops from crevices in the roof; as it evaporates, the bicarbonate breaks down, carbonic acid is freed and the calcium carbonate crystallizes in icicle forms, giving the stalactites. The ground splash, evaporating similarly, makes the stalagmites which grow upward to meet their pendent parents. The most remarkable of these limestone caverns are the Adelsberg Grotto, in Carniola, and the Aggtelek Cave, in old Hungary. The former, including its ramifications, is over five miles in extent, and disputes with the Aggtelek the

THE ENTRANCE TO THE GREAT PEAK CAVERN, IN DERBYSHIRE, ENGLAND

title of the longest in Europe. It has been explored for more than two miles, and the River Poik, which penetrates it, can be followed for half a mile. The cavern expands here and there into chambers, and the largest of these, the Franz Joseph and Elizabeth Grotto, is 223 yards long and 214 yards broad. W. H. Davenport Adams says, "There is not, perhaps, another cavern in the world so distinguished by a character of grandeur and boldness. The irregularities of its surface, the fissures torn in its vast sides, its deep shadows and gloomy hues, form a striking contrast with the regular beauty and symmetrical grace of the whitely gleaming and transparent concretions suspended from the roof, and reflecting in all directions the flashing light of torch and taper."

In the cave is found the curious eel-like animal called Proteus, which having gills and lungs, can live under water and in air.

There are no other caverns in Europe so large as those just mentioned, but there are many more beautiful. France has the Grotto of La Balme, the Grotto des Demoiselles, the Grottoes of Arcy and the Grottoes of Osselle, all adorned with fantastic and beautiful stalagmites and stalactites. In Belgium we may visit the wonderful Grotto of Hansur-Lesse. Greece boasts of the Grotto of Antiparos, situated on the Island of Antiparos, which many consider the most beautiful stalactitic cavern in the world. It contains a superb stalagmite, 24 feet in height and about 20 feet in diameter at its base, which is known as "The Altar", since Mass was celebrated upon it in 1673.

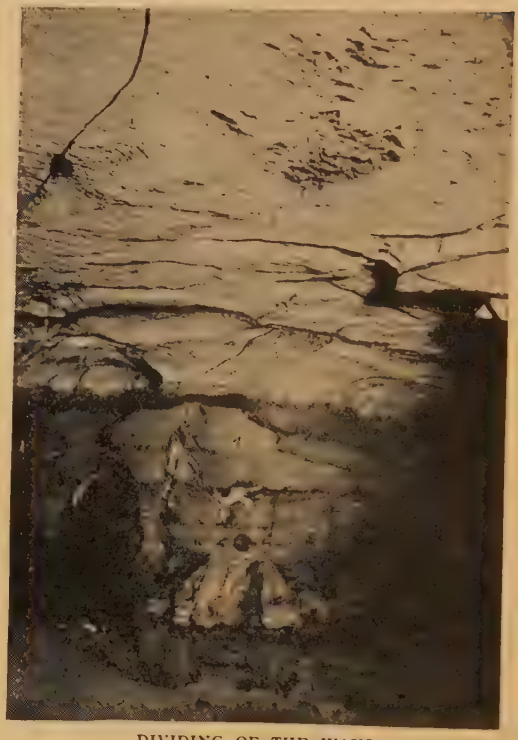
The greatest limestone cave in the world is the Mammoth Cave, in Kentucky, with 223 known avenues, of an average width and height of seven yards, and of a total length of over 100 miles, representing an erosion of 12,000,000 cubic yards of limestone. A French traveler making a tour of the world declared that no spectacle, not even Niagara Falls, impressed him so much as this cave. Bayard Taylor said: "It is the greatest natural curiosity I have ever visited, Niagara not excepted; and he whose expectations are not satisfied by its marvelous avenues, domes and sparry grottoes must either be a fool or a demigod."

THE GROTTO AT MORGAT, BRITTANY

Naturally, in a cave of this size there are many large rooms; about fifty-seven are known, and each has been given a distinctive name, such as the Gothic Church, Bacon Chambers, Ole Bull's Concert Room, Mary's Bower, Mary's Vineyard, Lucy's Dome, the Star Chamber, etc. The largest chamber, named the Chief City, is 450 feet long and 130 feet wide. Some of the Chambers are very lofty, the Stella, Mammoth and Gorin's domes are about 250 feet high, and Lucy's Dome is over 300 feet high. The Cleveland Avenue is 60 feet wide, 20 feet high and two miles long. Bayard Taylor's description of the mighty cavern may well be quoted here:

INTO THE DEPTHS OF MAMMOTH CAVE

ECHO RIVER



DIVIDING OF THE WAYS

Photos Brown Bros.

POMPEY'S PILLAR

MAMMOTH DOME

"We first entered the Snowball Room, where the gnome children in their sports have peppered the grey walls and ceiling with thousands of snow-white projecting discs so perfect in their fragile beauty that they seemed ready to melt away under the blaze of your lamp. Then commences Cleveland's Cabinet, a gallery of crystals the richness and variety of which bewilder you. It is a subterranean conservatory filled with the flowers of all the zones, for there are few blossoms expanding on the upper earth but are mimicked in these Gardens of Darkness. I cannot lead you from niche to niche and from room to room examining in detail the enchanted growths; they are all so rich and so wonderful that the memory does not attempt to retain them. Sometimes the hard limestone rock is changed into a parterre of white roses; sometimes it is starred with opening daisies; the sunflowers spread their flat discs and rayed leaves; the feathery chalices of the cactus hang from the clefts; the night-blooming cereus opens securely her snowy cup, for the morning never comes to close it; the tulip is here a virgin, and knows not that her sisters above are clothed in the scarlet of shame.

"In many places the ceiling is covered with a mammary crystallization, as if a myriad bubbles were rising beneath its glittering surface. Even on this jeweled soil which sparkles all around you grow lilies and roses, not singly overhead, but clustering together towards the base of the vault, where they give place to long, snowy pendulous cactus flowers, which droop like a fringe around diamonded niches. Here you see the passion flower, with its curiously curved pistils; there an iris with its lanceolate leaves; and again bunches of celery with stalks white and tender enough for a fairy's dinner. There are occasional patches of gypsum, tinged a deep amber color by the presence of iron. Through the whole length of the avenue there is no cessation of the wondrous work.

Photo Brown Bros.

THE EAGLE'S WING, MAMMOTH CAVE, KENTUCKY

The pale rock-blooms burst forth everywhere, crowding on each other until the brittle sprays cannot bear their weight, and they fall to the floor. The slow, silent efflorescence still goes on as it has done for ages in that buried tropic." In Mary's Vineyard the stalactites take the form of clusters of luscious grapes burdening hundreds of dewy boughs. The Star Chamber is named from its starry roof, black with binoxide of manganese and studded with snowy points of calcite gleaming like stars in a moonless sky of midnight black.

Besides these chambers, the Mammoth Cave contains eleven lakes, seven rivers, eight cataracts and thirty-two abysses. Lake Lethe is a body of water about 400 feet long and 40 feet wide, and the River Styx has about the same dimensions. Echo River is from 20 to 200 feet wide, and about three-quarters of a mile long and communicates with Green River through a subterranean passage. The extraordinary echoes produced by agitating the water with the boat's paddle are particularly beautiful. "The first sound that broke the stillness was like the tinkling of silver bells. Larger and heavier bells then seemed to take up the melody, as the waves sought out the cavities in the rock. And then it appeared as if all chimes of all cathedrals had conspired to raise a tempest of sweet sounds. They then died away to utter silence. We still sat in expectation. Lo, as if from some deep recess which had been hitherto forgotten, came a tone, tender and profound; after which, like gentle memories, were reawakened all the mellow sounds that had gone before, until River Hall rang again."

It might be thought that the air in these deep recesses must be impure and heavy, but, on the contrary, it is exceptionally pure and exhilarating. Professor Silliman suggested that the percentage of oxygen might be higher than in outside air owing to the amount of nitrogen consumed in the formation of niter-beds in the cave, but so far this has not been analytically proved. Not only is the air pure and exhilarating, but it is, of course, free from germs and of very constant temperature. However hot or cold it may be in the outer air, the temperature of the cave remains constant at about 53° to 54° F., the winter mean being the former figure and the summer mean the latter. In view of the purity of the air and the even temperature, it was thought that the cave might make a good sanatorium for consumptives, and in 1843 twelve cottages were built in the cave, and fifteen patients took up residence there. But the experiment, probably owing to lack of sunlight, was an utter failure.

The second largest cave in the world is the Wyandotte Cave, in Indiana, and, like the Mammoth Cave, it occurs in a limestone region. It has over twenty-three miles of avenues, and, though not so large as the Mammoth Cave, is in some respects more beautiful, and is said to have a greater number and variety of stalactites than any other cave in the United States. Its chief marvel is the "Pillar of the Constitution", a column of oriental alabaster 40 feet high and 75 feet in circumference. The temperature of the cave is the same as that of the Mammoth Cave.

A third enormous cavern is found at Luray, in Page County, Virginia. At some time, long after its original excavation, it must have been scoured with acid-charged glacial mud which eroded the already formed dripstone into beautifully grotesque shapes. Its stalactitic display is probably the finest known. In the canopy above the "Imperial Spring" no fewer than 40,000 stalactites are to be seen. The Swords of the Titans are 50 feet long and 3 to 8 feet wide, and when struck by the hand give forth sounds like tolling bells. Brand's Cascade is a mass of alabaster like a frozen cataract. "Imagine, if possible," says Hovey, "a great cataract of milk 30 feet wide and 40 feet high, rushing and copious, suddenly caught in mid-air and polished to a wax-like luster. And beyond it another smaller one, as yellow and golden as liquid amber. And then fancy this whole shining and glorious mass flooded by the dazzling brilliancy of electric lamps, and confess that it must rival the most wonderful scene ever pictured by pencil or pen!"

THE STAR CHAMBER IN THE MAMMOTH CAVE

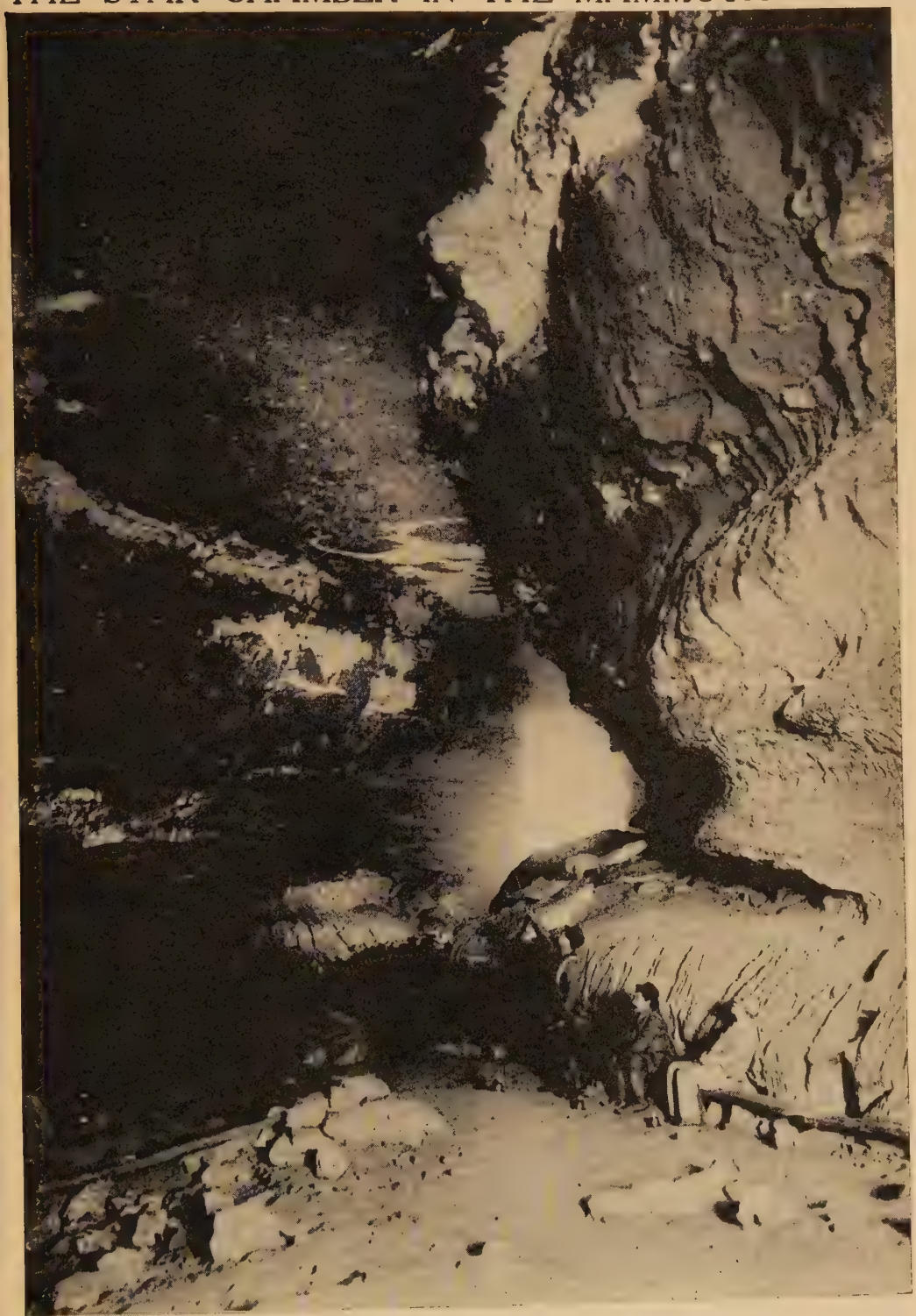


Photo Ewing Galloway, N. Y.

This flashlight photograph shows the famous Star Chamber in Mammoth Cave, Kentucky. When one enters it by lantern light, the black roof looks pale blue, and the white gypsum crystals sparkle like stars; one gets the impression of being out of doors again.

CURIOUS FORMATIONS IN CARLSBAD CAVE, NEW

THE ELEPHANT'S EAR IS ONE OF THE ANIMAL-LIKE REPRODUCTIONS

Wide World Photos

OPENINGS IN THE WALLS OF VARIOUS CHAMBERS ARE CONCEALED WITH DAINTY DRAPERIES

MEXICO, THE LARGEST KNOWN IN THE WORLD

SNOW-WHITE FORMATIONS THAT SUGGEST THE FROZEN NORTH

Wide World Photos

SOME OF THE DELICATE INTERIOR DECORATIONS LAVISHED BY NATURE

The temperature of the Luray Cavern is about 54° F., and the air is germless and almost optically pure. The Blue Grotto of the island of Capri, pictured on this page, deserves mention not for its size but for the interesting phenomenon to which it owes its name. This limestone cave, somewhat elliptical in form, a result of chemical and wave erosion, is about 1300 feet in circumference, the roof being 41 feet above the water. The sea flowing through the only entrance is 48 feet deep in the cave. When the sun shines outside, the light penetrating the water and reflected up into the cave gives everything, water, rocky walls and bristling stalactites, a beautiful blue color.

In November, 1923, another rival, and a formidable one, for the supremacy of the cave world was announced. In the Guadalupe mountains of New Mexico, near Carlsbad and close to the Texas line, in the limestone of the Carboniferous age, is a cave said to equal, if not surpass, even the Mammoth Cave. There are three entrances to this natural marvel, one descending to a depth of 750 feet. One circular room, the King's Palace, 300 feet in diameter, has walls and ceiling hung with stalactites of every color of the rainbow. Another room, the largest known of underground chambers, is 5000 feet long, 600 feet wide with a roof varying from 100 to 300 feet high.

This Carlsbad cave is now being explored and mapped by government geologists with a view to incorporating it in a new national park.

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THE BLUE GROTTO, CAPRI

MEDICINE OF TOMORROW

Revolutionary Changes that are Proceeding Alike in Surgery and in Medicine

RIVALRY OF CHEMISTRY AND THE KNIFE

FOR once, here is a case where we may prophesy, because we know. The future developments of medicine are already crowding upon the present, and none can doubt them. The sooner we are prepared to understand them, the sooner they will be realized. First, let us observe the paradoxical fate of antiseptic surgery, the great surgical method which we discussed in a former chapter. Here is the most beneficent achievement of the human mind coming to its maturity within a generation, when all preceding generations had gone without it; and now it is about to undergo the most extraordinary decline in its scope, after threatening to supersede all other forms of treatment.

Hitherto, in its brief and brilliant career, antiseptic surgery has advanced from one part of the body to another, and from one type of malady to another, until mere medicine, the future of which we propose to discuss, threatened to disappear altogether. The surgeon has advanced from the limbs to the trunk, from the abdomen to the cranium, and from the cranium even to the heart, until it seemed as if the knife were to be Life's best champion. Even where organs had degenerated, like the kidney in Bright's disease, and were tightly strangled in their capsule made thick and rigid by long inflammation, the surgeon has tried to strip off the "strait-jacket" of the gland, and so to restore its blood-supply and its health.

But here we must proclaim a new stage in the history of surgery, a stage in which the very discoveries that made it possible will supersede it in large degree. Let us take, for instance, what is usually called "surgical tuberculosis". A child has a "white swelling" of the knee-joint, which yields to no remedies. Later, he suffers from starting-pains at night, and serious lameness. After injections of iodoform and other remedies have been tried, antiseptic surgery is called in. The surgeon exposes the knee-joint and removes it bodily. He apposes the thigh-bone and the shin-bone, each with a perfectly healthy raw surface, the disease having been completely removed, and they soon unite, giving the patient a single shaft of healthy bone from hip to ankle. This is a remarkable achievement, which has saved scores of thousands of legs in the past twenty-five years or so, and is evidently much to be preferred to the cleanest amputation.

But what of the two chapters in which we discussed the struggle for life between man and the tubercle bacillus? Clearly this is a case where we want something better than the best surgery — or perhaps we want something which corresponds to that latest development of surgery, which we call aseptic. The principle of that method is to prevent microbes from ever reaching the tissues of our patient. Let us apply this principle to the care of our children, to the milk they drink, to the food they consume, to their surroundings, — the nursery, the home, the school and the playground — and there will be no more tuberculous knees for the surgeon to cut out.

"Surgical tuberculosis" must be responsible for thousands of deaths annually, to say nothing of the pain, the deformity, the inefficiency and the expense which it causes. Good surgery can do and does great things here; but the wards and out-

patient departments of all our general hospitals are besieged by cases of the disease, and there are not enough competent surgeons in the civilized world to meet the whole of the need. Yet the reader who has studied the matter will not doubt that, when we once take proper care of our food and milk supply, surgical tuberculosis will have joined leprosy and typhus in the limbo of the bad old days. There will be an end, then, both of surgery and medicine so far as this disease is concerned. Even the finest and most efficient anti-tuberculosis serum, not yet invented, will be as superfluous as the surgeon's knife.

How entire fields of surgical activity will disappear with preventive care

The largest of all the fields of surgery will thus disappear altogether. It furnishes a type of the many microbic diseases against which modern surgery fights, and which may be abolished altogether. Of another order is the case of rickets, to which we have referred previously, because of the great achievement of surgery in relieving knock-knees. But rickets is an entirely unnecessary and inexcusable disease. It is not "congenital", but the post-natal consequence of post-natal malnutrition. It will disappear when instruction in the elements of infant and child feeding is given to all girls in our schools, even at the cost of inattention to subjects of lesser importance. Here the promise of the future is that there shall be no more need for either medicine or surgery. We should remember, also, that though the surgeon is apt to think of rickets as a disease of the bones, the pathologist knows that this is a disease of all the tissues, involving malnutrition of the brain as well as of the skeleton, so that no surgery can ever remove all its consequences. We should do better to give children enough good bread and milk, and fruit juice and say good-by to all kinds of saws and syrups.

Expected cure of the microbic diseases by the use of anti-toxins

The present surgical requirements of such a disease as syphilis cannot much longer be in demand. Shortly we shall see how medicine will come back to its own again in this field, using weapons infinitely subtler than the cleanest knife. As for the ally of syphilis, which is responsible for such incessant surgical need among innocent and ignorant women, it also must go to its own place before long. Only the stupidity, prudery and faithlessness of public opinion stand between science and the abolition of the disease which is responsible for one half, at least, of all the cases where abdominal surgery is required by women.

In men the commonest need for abdominal surgery is due to appendicitis. Many thousands of operations yearly, in this country alone, are required by this disease. But our standard keeps on rising. A decade or two ago it seemed an almost supreme triumph of the human genius that the surgeon should be able to cure appendicitis and avert peritonitis by means of a daring operation which involved opening the body of a living man. Such hosts of people, now alive and well, owe their lives to this procedure that we can scarcely decry it. But we begin to see that the knife is much too clumsy for us to rest content.

We must ascertain the dietetic errors upon which, beyond much doubt, the occurrence of appendicitis will be found to depend, because they favor the growth of the microbes which cause the disease; and even sooner than that we may be provided with something comparable to the diphtheria anti-toxin, which will control the inflammation in its earliest stages, and render the use of the knife superfluous.

The fading belief in the appendix as an "ancestral relic"

Here a special note must be made regarding the appendix. The accepted view of years ago was that this is an organ useless in man, a kind of "ancestral relic" which is interesting to the evolutionist because it speaks of past stages in the history of our species, and illustrates certain theories of organic evolution. The surgeon might argue that his knife simply hastened the natural evolutionary process by which the appendix is becoming decadent in our species.

Enthusiastic surgeons have indeed argued that the appendix should be removed from every infant within the first fortnight, in order to prevent appendicitis, and hasten the slow processes of organic evolution. The appendix has been spoken of as one of the organs which remain in our bodies though they are useless, and of which the surgeon may rid us today, though our posterity will be rid of them by means of the progress of organic evolution.

The evidence that the appendix is not a decadent organ

Comparative anatomy gives us quite another view. The appendix is not a decadent organ at all. The lower mammals do not possess it. Only when we reach the anthropoid apes and ourselves do we find an appendix appearing. It is not the shrivelled remains of some digestive organ which we find in full size in the horse or the cow or the reptile. It is a comparatively recent addition to the alimentary apparatus. The anthropoid apes possess this organ, and in them it is doubtless useful. It may be useful in ourselves, for all we know; the fact that we can do without it may merely mean, as in many other cases, that some other organ assumes a compensatory function in place of it. Professor Arthur Keith, one of the greatest authorities, says in his admirable book on "The Human Body" that, "So far we have never known of appendicitis occurring in anthropoids in a state of nature, but they do become liable to this disease when kept in captivity and fed on a human diet." A little later he speaks of the order of mammals to which we belong as having "acquired an appendix".

How antisepsis and the knife hold the field for the moment

Thus we see that exact knowledge entirely reverses the view formerly held and popularly quoted. As in some other cases, we have been inclined to blame nature because we were abusing her and she resented it. In the light of recent knowledge we can no longer encourage the surgeon, emboldened by the impunity of his most daring procedures, to remove whatever parts of the body we have not yet succeeded in discovering a use for. It would be better to revise our diet, perhaps, and be content to possess a functional appendix, doing some useful work for us, no doubt. We must admit that the appendix contains lymphoid tissue, the same tissue which elsewhere produces white blood-cells, so that it may help to provide us with those invaluable defenders, even if it does nothing else.

Study of the chemistry of the body as the pathway of hope against cancer

It may now be taken as practically certain that cancer is not a microbic disease. The malignant tumors, including cancer and sarcoma, still defy elucidation, as do their innocent allies, the fatty and muscular and other "benign" growths. For the present, drastic surgery holds the field, and does great service, no doubt. Indeed, it is the duty of all who write for the public eye to insist that surgery should be had recourse to at the earliest possible moment in cases of malignant disease, whatever else be done.

But the prospect of something far better is extremely hopeful, and at any moment the discovery may be made which will forever banish the knife from this field. The public opinion that there is something peculiarly hopeless about the problems of cancer is not shared by experts. On the contrary, so much definite progress has been made within the past decade that the time can scarcely be very far distant when the knife will be rendered superfluous by the introduction of chemical substances in the presence of which malignant cells cannot live. There are those who believe that such substances can already be named for it has been observed that cancer seems to prefer a medium that is acid. Thus in the stomach we often find cancer whereas in the small intestine cancer is practically unknown. The stomach juices are acid; those of the small intestine are alkaline.

The key to the solution of this problem, and to the replacement of surgery by a better medicine in the treatment of malignant disease, is hoped to be found in that great department of the study of life which

is called bio-chemistry, and of which the biology of the future will more and more consist. The best hope lies in the very fact that cancer is now being studied by biologists, as part of the problem which living tissues offer for their solution. We must study the chemistry of those human or animal patients in whom there occurs spontaneous recovery from malignant growths. Hitherto, such cases have been too much regarded as mere curiosities, which did not demand the help of the surgeon, and were therefore of no further interest to him. On the contrary, they may contain the hidden solution of the problem, and hope in that solution is being found by the men, not surgeons, but students of the living cell, who are engaged upon that task.

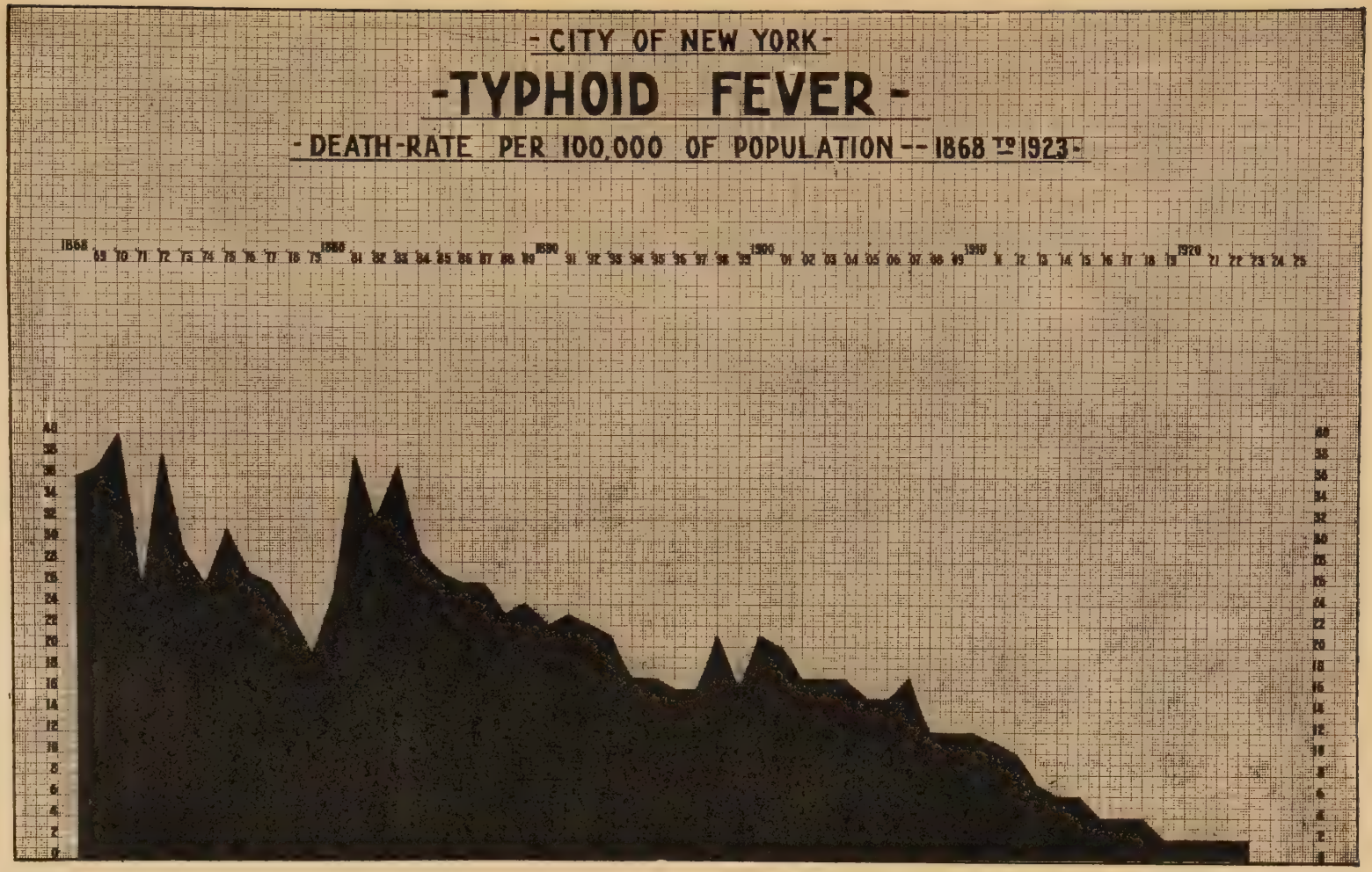
Recent discoveries suggesting we are on the track of curative knowledge

For instance, certain cytologists, or students of the cell, claim to have made a remarkable discovery a few years ago, which has guided subsequent research. They claim to have found that the cells of a cancer had only half the number of chromosomes in their nuclei that is characteristic of the species in whom the cancer is occurring. In other words, as we may recall from our study of the genetic process, they maintain that the malignant cell has the same number of chromosomes as a germ-cell, formed by the process of gametogenesis. Another student, Dr. John Beard, of Edinburgh, has shown that this feature of the malignant cell corresponds to the facts of the alternate or asexual generation which alternates with the sexual generation in many animals and plants, and he has suggested a line of treatment, on this view, which may yet prove to be our salvation.

Another student, a brother of Ronald Ross, has studied the subject from the standpoint of cytology, and has found some of the conditions under which abnormal division and multiplication of cells can be induced and controlled. The problem of cancer at large cannot here be discussed, but it is enough for us to realize that it will yet become a medical and not a surgical problem in the individual patient, and that it will be solved not at all by the methods of traditional medicine, but by biology, by the fundamental study of the behavior, and especially the chemistry, of living cells. The branches of biology called entomology and protozoölogy have found for us the insects that convey disease; and the protozoa, or humblest animals, that are responsible for such diseases as malaria. Now, the branch of biology called bio-chemistry is striving to solve for us the problems of cancer. In the United States, we may add, much has lately been done in the way of experiment upon isolated portions of living bodies — a strip of mucous membrane, a fragment of the kidney, liver and so forth. Clever cytologists have been able to keep these minute living fragments alive for long periods, by means of proper temperatures and suitable nutrient media, and the same has been done for portions of malignant tumors. Thus we are beginning, slowly but surely, to learn the conditions of their growth, and the nature of the nutrient solutions which suit them best and worst. Before very long we may hope to apply such knowledge to the living patient, and to cure him certainly, painlessly and rapidly — as now and again a patient cures himself, to our astonishment and delight.

The science of immunity the hope of future medicine

It will be plain to the reader that, with the introduction of an efficient chemical antidote to cancer, and of anti-sera and similar bodies for microbic infection, the sphere of actual surgery in the future will be much contracted. To anyone who has any idea of the subtlety and delicacy of the living body and of the living cells of which it is composed, even the cleanest knife must appear a brutal and barbaric instrument. It is bio-chemistry, or the chemistry of life, that will yearly make this clearer, meanwhile giving us more and more control over vital processes in all their stages. The remoter promise of the future thus excludes the knife altogether from the armory of the healing art, except in cases of accident. The sole other sphere that will otherwise remain for the surgeon will be in the care of maternity.



"PUBLIC HEALTH IS PURCHASABLE, WITHIN NATURAL LIMITATIONS A COMMUNITY CAN DETERMINE ITS OWN DEATH-RATE"

Medicine, of a new kind, will return to its place of preëminence, as in the days when the surgeon was a barber-surgeon, and the physician was a being of a loftier order. But the physician of the future will merely be the instrument through which his patients profit by the labors of the chemist Pasteur and the surgeon Lister, and one or two physiologists besides.

The great lines of future progress, and the work of the pioneers along those lines, must here be briefly considered. In our study of health, in another section of this work, we saw that the healing power of nature, the "vis medicatrix Naturæ" of the ancients, counts for much. This healing power begins to take tangible form in our day. Reference has already been made to the inimitable virtues of thyroid extract in the diseases of mind and body called cretinism and myxœdema. That discovery is now nearly a generation old, and we naturally have meanwhile sought for similar advantages from the use of other of nature's "materia medica". The suprarenal or adrenal glands have given us the useful but not actually curative substance called adrenalin. Bone marrow is credited with much value by all physicians. The thymus gland, which lies just in and below the root of the neck in infancy, but disappears almost entirely thereafter, has been employed in various diseases, like the thyroid. The pituitary gland, a curious, small structure at the base of the brain, has been similarly used, in insanity and various other conditions. This gland is enlarged in cases of gigantism. If the enlargement occurs during youth, the subject becomes a giant; if later, the overgrowth takes a morbid form and the disease called acromegaly (the enlargement of all prominences) is produced. Hence pituitary extract may be employed in order to increase the height.

This by no means exhausts the experiments that are being made in this direction of organotherapy, or opotherapy, as it is called in Europe. At the time of writing, none of the results, generally recognized, have been worthy of comparison with those obtained by the use of thyroid extract. That instance, however, proves beyond dispute that a true and fruitful principle is here involved. We shall go on until we find many more applications of it. Extracts of the brain, of the kidneys, the liver, the reproductive glands, the muscles and so forth, are all being experimented with. Mostly or wholly they fail; but that may be because our chemistry is not yet delicate enough. It suffices for thyroid extract, which does not fail. The most recent hope is furnished by the gland called the pancreas, which has a great influence upon digestion, and which has lately been proved to influence the utilization of sugar in the body. When certain parts of the pancreas, namely the Islands of Langerhans, are diseased, and do not do their mysterious work, the sugar in the blood is not properly employed, and the patient becomes the victim of a form of diabetes, called "diabetes mellitus". Only recently has Dr. F. G. Banting, of the University of Toronto, succeeded in isolating the active principle found in the internal secretion of the pancreas. He calls it "insulin" and experiments have already proved that diabetes can be cured by the injection of this substance into the blood stream of patients suffering from this disease. But they do not stay cured. The injection must be continued daily to be effective, otherwise the diabetes returns. However, by the intelligent use of "insulin" and by attention to diet, the sufferer from diabetes can maintain life and health for many, many years. But there are still hopes

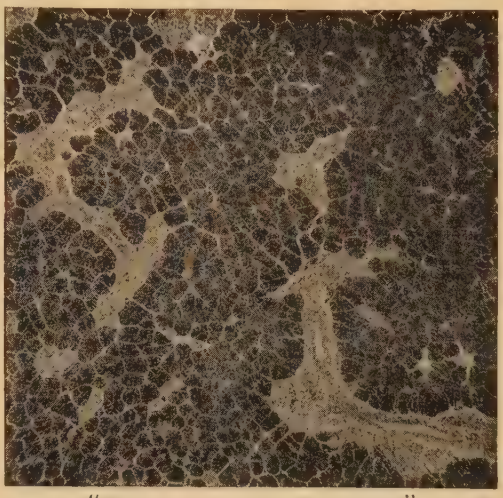
AVERAGE ANNUAL DEATH-RATE FROM DIPHTHERIA PER 10,000 POPULATION

City	Before Use of Anti-Toxin	After Use of Anti-Toxin
New York	15.19	6.62
Boston	11.76	6.34
Baltimore	7.34	4.99
Chicago	14.29	5.13
Paris	6.41	1.49
Berlin	9.93	2.95
London	4.85	3.88
Vienna	8.14	2.95

The comparisons above between the death-rate from diphtheria in certain large cities of the world, before and after the introduction of the diphtheria anti-toxin, illustrate the great saving of lives that has been brought about through its use.

that the continued administration of this preparation of the pancreas may compensate for the lost activity of these cells, just as in the case of the thyroid gland. Other observers in this country, in England and in Germany, have found reason to hope that the use of the active principles of this same organ may some day enable us to conquer malignant growths, with which they seem to have some connection, according to the German chemists in especial.

So much for this line of progress, along which the medicine of the future will surely have much to add to our single established achievement with thyroid extract. Now let us look at the magnificent work that has been done upon the lines which Pasteur initiated. We may conveniently deal with the special studies of the two most illustrious pupils of the French master, Lord Lister and Robert Koch. Those two represented the first generation of Pasteur's spiritual descendants. The first applied the sheer discovery of his master in one field. The second amplified the discovery by adding to the known parasites of disease; above all, by his discovery of the tubercle bacillus. The men of the next epoch, Professor Elie Metchnikoff and Professor Paul Ehrlich, have neither of them discovered the microbe of any disease. In a sense, their work lies deeper, though that work must, of course, come first. For, indeed, our science has really only just begun when it seems to culminate in the discovery of, say, the tubercle bacillus.



"THE ISLANDS OF LANGERHANS"

A section of the pancreas magnified 40 times. The darker sections represent tissue which secretes pancreatic juice. The lighter colored, irregular patches are areas of islet tissue secreting insulin.

Such a discovery closes a long chapter; but it opens a new one, just like the discovery of radium and radioactivity, or that of gravitation, or that of organic evolution, or Mendel's law. Plainly, we have now to ask why and how the parasite hurts

Photo by Mr. Lyonde, Toronto

DR. F. G. BANTING

The discoverer of insulin.

Photo by Mr. Lyonde, Toronto

C. H. BEST, M.A.

Dr. Banting's collaborator in the discovery of insulin.

us, how we resist it, or fail to resist it, and what are the laws of the long process of interaction and combat between the two species, the parasite and the host.

The facts are not simple. Two men are both infected with the same parasite — with similar portions of the same culture, or from the same previous patient. One dies, and the other never displays a single symptom. A third man might display grave symptoms, and then recover. Why these differences? Plainly, the discovery of the parasite merely ushers us to the threshold of a new science, which we may call the science of immunity. The converse of immunity is susceptibility, and we combine the study of the two, for they are really one, and the terms are purely relative to one another.

It may fairly be said that the medicine of tomorrow, in so far as it is not simply preventive medicine, will be concerned with the practical applications of the science of immunity. The founder of this science is undoubtedly Professor Elie Metchnikoff, the famous Russian, who worked at the Pasteur Institute in Paris. We have already seen that Pasteur's own theory of acquired immunity was unsatisfactory. It is not true that we become immune because some special substance, which the microbes need and consume, is exhausted, and so they die of starvation. The triumph of the diphtheria anti-toxin proves that immunity depends upon something more positive than that.

The epoch-making discovery of the leucocytes and the phagocytes

Late in the 'sixties it had been noticed that the white cells of the blood can pass through the walls of the blood-vessels and wander about in the tissues. This is known as the "emigration of the leucocytes". It is a remarkable phenomenon to observe under the microscope, for we must remember that the wall of a blood-vessel is entire, and that the emigrating leucocyte makes no perforation, and leaves no leakage. But it is a thousandfold more remarkable to interpret, involving, as it does, ideas of purpose in the minute, independent individual cells of our bodies.

In the following decade, many workers, including Koch, observed microbes inside certain leucocytes. It was supposed that the microbes, attacking all parts of the body, had attacked and invaded the white cells. No function whatever was at that time known or plausibly guessed for these cells.

The action of the leucocytes and phagocytes in bodily defense

In the next decade, the 'eighties of the last century, Metchnikoff set to work in the most thorough and final fashion. He proved that the white cells originate in the same part of the body as that which forms the digestive tract, so that we might well expect them to have digestive powers. He proved that, in the water-flea, in which the emigration of the leucocytes was first observed, those leucocytes will engulf and digest the spores of a parasitic fungus, experimentally introduced. He studied the white cells in "a great variety of animals, from goldfish to alligators", and he found the facts to be the same in every case. They were "eating-cells", or phagocytes, and thus he founded the theory of phagocytosis, of which Lister said: "If ever there has been a romantic chapter in the history of pathology, it is the story of phagocytosis."

It was necessary to guard against various possible fallacies. We have no right to assume that the white cells do what they seem to do until we have demonstrated, first, that the microbes do not invade them, and second, that the microbes are not killed, by some other means, before the phagocytes eat them. The process will wear a very different aspect if it can be shown that the phagocytes merely dispose of the bodies of the slain, and play the part of scavengers, instead of soldiers. For if that can be shown, plainly our theory of immunity cannot yet be stated, and we must find the agents which, in point of fact, do the essential killing of the invading host.

Metchnikoff and his pupils met these difficulties in large measure; we shall learn from his great German rival, Ehrlich, to what extent the early criticisms had some

foundation. He showed that the phagocytes ate living microbes, which could be recovered and restored if they had not been too long consumed. Latterly, we have obtained evidence to show that the phagocytes do undoubtedly produce and use digestive ferments, which can be, to some extent, isolated from them, and there is no doubt that they do play an essential part in the processes of immunity. This part will depend, in some degree, upon the sheer numbers of the leucocytes, and, further, upon their particular powers. But it thus becomes a matter of importance to know what is the number of the white cells in the blood of the patient, in almost all forms of disease. In some cases we find that their number is diminished, as in most forms of cancer and in chronic alcoholism (two forms of disease which are known to have some association); and in many other cases the number of leucocytes is increased, producing the state of the blood which is technically known as leucocytosis. This is an alarming phenomenon, or a reassuring one, according as we look at it. It is alarming, as fever is alarming, if we recognize in it an indication of disease; but it is reassuring if, admitting the existence of the disease, we see in the leucocytosis an attempt to counteract it.

Thus, in the victim of the minute double (or diplo) coccus which causes pneumonia, we are glad to observe a high leucocyte count, for we believe that this means a great multiplication of the army of defense, and we know that the failure of the body to produce leucocytosis, when it is attacked by the *pneumococcus*, is of ill omen. Finally, we need only note that the substance known to the surgeon as pus largely consists of dead and dying phagocytes, which have emigrated from the blood-vessels, and have been overwhelmed in the attack upon invading microbes, say, in an inflamed finger or toe, or in appendicitis, to choose extreme examples.

If now we recall the facts of the diphtheria anti-toxin, we see that, notwithstanding the truth and value of the theory of phagocytosis, there must be more for us to discover. Whence and how comes the anti-toxin produced, or found, in the blood of the child, or the horse, in whose body the diphtheria toxin has been at work? Is this anti-toxin produced in the blood, where we find it, by a form of leucocytes? Or is it produced by the cells of the throat, which the diphtheria bacillus is attacking, and is it thence absorbed into the blood? Evidently it looks as if something besides the phagocytes played a part in the acquirement of immunity in this case.

Long ago, we remember, the ancients had a *humoral* theory of disease, according to which certain humors, made in the body, affected its condition, and that of the mind

PROFESSOR PAUL EHRLICH

— as when we say, "It is his humor," and hence, "I humored him." This ancient view is now to be revived in a new form, for we can demonstrate the existence of fluids or humors in the blood, which determine, for instance, our recovery from disease. The question is, how far does such a discovery qualify the phagocytosis theory? We can prove that the fluid part of the blood contains substances which kill certain germs. For more than thirty years it has been known that the ordinary blood serum of a rabbit will kill anthrax bacilli. In other words, the blood serum is antiseptic; *not*, be it observed, in general and at large, as carbolic acid is, but specifically

antiseptic towards certain microbes. These substances in blood serum which kill bacteria may accordingly be called *bactericidal*, and evidently we must add a recognition of them to our theory of phagocytosis. When we do so, it is open to Metchnikoff to reply, as he has done, that these bactericidal substances in the blood serum — the fluid part of the blood — have been produced by the phagocytes, and have overflowed into the serum from them. That may be so.

Already we have gone far enough to understand certain facts. In many instances, when parasites attack us, we are either not made ill at all, or else we suffer very little, and are speedily well again, though those parasites have never attacked us before, and though certainly nothing the doctor gives us has made any essential difference. We have, in some degree or other, a *natural immunity* against the attacks of that kind of parasite; and this immunity may be traced to the presence in our blood, first, of phagocytes, and, second, of bactericidal substances (however produced) which kill the invaders. In the past this question of natural immunity has been almost wholly ignored by bacteriologists and doctors, and very excusably so. "The whole need not a physician." The urgent problems are those of the patient who has not natural immunity enough, and our intensest interest is bound to center in the problems of *acquired immunity* for such patients.

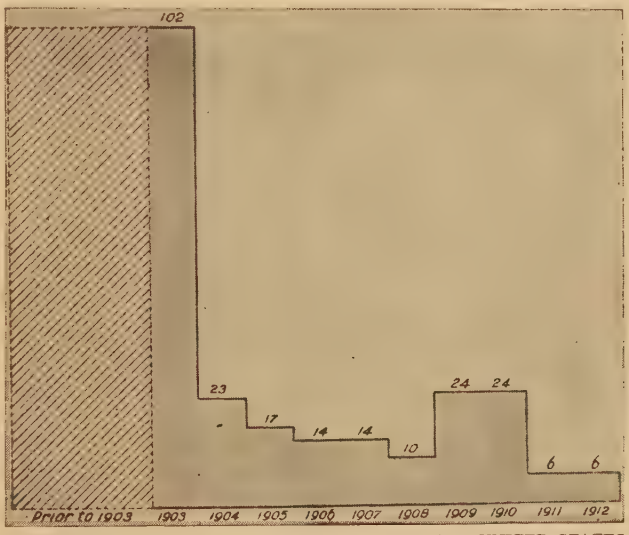
But from the point of view of Life, and general biological problems, natural immunity is one of the most fascinating subjects in the world. For how was it acquired? Whence the presence of these admirably fitted substances in the reader's blood, exactly *made* to checkmate certain microbes, which his body has never experienced? His body was developed from a single microscopic cell, and somehow, somewhere, in the structure and potentialities of that "zygote", were the antecedents of this bactericidal serum, which no ordinary chemistry can imitate. It seems hopeless for us to form any theory of the presence of such substances in the blood, unless we invoke a certain theory of heredity, which is in very poor favor at the present time. We seem compelled to argue that the parents (or one parent) of the individual have suffered from this parasite themselves, that a bactericidal substance has been produced in their blood serum, and that this *acquired immunity* of theirs is handed on so as to become *natural immunity* in their offspring. In other words, here we are accepting the famous Lamarckian theory of the "transmission of acquired characters".

The neo-Darwinians will have none of such a theory. They admit that races appear to become resistant to many diseases in proportion to their experience of them, but they deny that this immunity is due to the natural inheritance by offspring of a character painfully acquired by parents. They explain the facts in another way. They say that individuals vary naturally in their resistance, by pure chance, and that natural selection, working by means of the disease-parasites, constantly tends to weed out from each generation those individuals whose natural immunity is low, while those whose natural immunity is high survive, and hand on their natural, *not* acquired, trait to their offspring. The practical importance of this controversy is transcendent, for if the neo-Darwinian view be correct, the only way in which to get a race that can resist, for instance, tuberculosis is to let that disease run riot for as many generations as need be, until all the susceptible stocks are weeded out, and the resistant remain. On this view, all the objects and methods of preventive medicine, and all the devices whereby doctors keep their patients alive, are futile, and worse, leading only to the perpetuation of susceptibility, and, therefore, of disease (whenever the parasites get a chance at all), in future generations.

Here we regard this view as false, and we reject it, as the majority of contemporary students are coming to reject it, on the ground that the neo-Darwinian theory of the *chance* origin of immunity is incredible. We find the bactericidal substances, and the whole machinery of defense, in the body, to be so subtle, exquisite, complicated, exact, that the theory of its origin by sheer chance, without any reference to its purpose, is ridiculous. It would be

much easier to believe that a relatively simple thing like an automobile had fallen together by chance, though not even the neo-Darwinians could be so credulous as to believe that.

But what of acquired immunity, for therein will center the medical achievements of the immediate future? Here our great master is Ehrlich, of Frankfort. To him we have recently been indebted for the organic compound of arsenic which kills the parasite of syphilis, and which, being number "606" in the list of substances which he experimented with, is often known by that number. This discovery, which has already been of the utmost value, must be directly traced to the discovery of the parasite of syphilis by Schaudinn, for it was the study of the chemical substances which most markedly affected this parasite outside the body that led to the construction of "salvarsan", or "606", for its destruction inside the body. This discovery has made Professor Ehrlich's name familiar to all readers, but it has long been honored by students of disease for his celebrated "side-chain" theory of immunity.



RESULTS OF THE TETANUS ANTI-TOXIN IN THE UNITED STATES

This diagram shows graphically the results of a campaign instituted in 1904 to reduce the number of cases of tetanus resulting from accidents during the Fourth of July celebrations by giving the sufferers doses of the anti-toxin. The figures put over the columns represent the cases of tetanus per thousand cases of injury.

This theory is much too complicated for discussion here, but it explains the proven fact that at least two substances are required in the blood before immunity can be established. One of these kills the microbes, but the other has first been necessary in order to make the microbe vulnerable. It holds on to the microbe with one hand, so to say, and holds on to the deadly bactericide with the other, and so links the two together. To this substance Ehrlich has given the name of "amboceptor", or two-catcher. The anti-toxin of diphtheria is doubtless an amboceptor, figuratively holding on to the bacillus with one hand, and introducing the bactericidal substance in the serum to it with the other.

Lastly, we have the interesting observations of the English bacteriologist, Sir Almroth Wright. He believes that he has discovered in the blood serum a kind of substance which he calls "opsonins" — *i.e.*, cookers — which, so to say, cook the microbes before the phagocytes can eat them. On this view, the phagocytes are of small importance, and it is the opsonins that matter most. It is supposed that the condition and the prospects of the tuberculous patient, for instance, can be estimated by counting the number of tubercle bacilli that his white blood-cells will consume in a given time, for this is supposed to furnish an index of the opsonic power of the particular blood serum in which the experiment is conducted. Among substances already proved to be useful, which have been obtained by such studies as these, we may point to the anti-diphtheritic serum, and to the anti-tetanic serum, which has often succeeded against tetanus, or lock-jaw, the anti-typhoid sera, invented by Wright and others, the anti-streptococcic serum, often valuable in erysipelas and puerperal fever and the anti-staphylococcic serum, often valuable in cases of boils and abscesses. The record is a good one, but it is vastly more promising than it is good. Great things are before us, thanks to the principles which we owe to Pasteur, Metchnikoff and Ehrlich.

BROWN GRASSES OF THE GREAT SALT SEAS

CORRALINE

SEA-GRASS

A MAGNIFIED BRANCH OF A MINUTE SEAWEED

HALIDRYS, WITH A GROWTH OF SEA-FIR

NOTCHED WRACK

KNOBBED WRACK

THE PLANTS OF THE SEA

Their Coloring and Susceptibility to Depth, to Temperature and to Saltness

VEGETABLE LIFE IN NEPTUNE'S GARDEN

THE study of life is always interesting, no matter what phase of it be chosen, but there is no more fascinating field than that of marine biology. There is always something mysterious about the living things in the sea — a feeling that no matter how much we may find out, there is more, much more, that remains undiscovered. Lands and continents may be explored and surveyed until not a square yard remains unknown, but no man can probe to the uttermost the depths of the ocean, nor examine more than a fraction of its contents. We know much of the monsters of the animal world that in olden times ranged its waters, and the largest forms of animal life still disport themselves there; but scientific knowledge of the plants of the sea is infinitely less advanced, and indeed has only in recent years made much progress.

Considering how universally distributed are the sea plants, or sea*weeds*, as we curiously term them, it is rather remarkable that ancient literature should have such sparse references to them; but, as a matter of fact, one finds only the most superficial mention of them. The Bible refers to them but once, in the words of Jonah, "The depths closed me round about, the weeds were wrapped about my head." Latin and Greek authors passed them over with similar contempt or ignorance. The earliest writers on biology frequently described many sea animals as plants, which is not surprising when we consider how unlike animals many of them undoubtedly are at first sight.

The prevailing color of land plants is the universal green, only relieved by the brilliance of the varied parts of the flower and the color of the bark of trees, but there is no such uniformity in the coloring of seaweeds. Indeed, it is their wonderful coloring that would first attract the attention of the observer looking at a forest of seaweed in clear water. Nothing more beautiful in coloring can be imagined. No wonder that the colors were taken as a basis of classification, a basis which still remains in the names given to the different groups. Thus we have the *Rhodophyceæ*, or red seaweeds; the *Phæophyceæ*, or olive-brown seaweeds; the *Chlorophyceæ*, or green seaweeds; and the *Cyanophyceæ*, or blue-green seaweeds. Nor is this such an unscientific method of classification as might be imagined, for it very nearly agrees with a classification that would be made were structure and mode of growth taken as the basis in the place of color.

When we look into this matter of coloring in sea plants, we find that it does not differ so fundamentally from that which obtains in land plants as would appear. In their ultimate color-composition the sea plants are all really green, just as are ordinary plants, and by virtue of the same pigment, chlorophyll. Where they differ is in having some other pigments in addition, the presence of which more or less obscures the green chlorophyll. Of these pigments there are four, termed respectively phycoerythrin, or the red pigment; phycophæin, or the brown pigment; phycoxanthin, or the yellowish-brown pigment; and phycocyanin, or the blue pigment. The discovery of these varied coloring matters explains at once the wonderful combinations and shades found in sea plants.

They all differ from chlorophyll in one important and interesting feature — namely, that they can be dissolved out of the sea plants by simply soaking them in fresh water, when the colored plants present the ordinary green of their shore relations. Chlorophyll is insoluble in water, and hence remains in plants so treated. Some fresh-water plants exist which are also colored similarly, but, nevertheless, these pigments are the special features of the sea plants, and their presence is due

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to the environment in which the plants pass their existence.

The colors of sea plants indicate in a somewhat rough-and-ready manner the depths at which the plants grow, though there are numerous exceptions. Thus the seaweeds found near the level of the high-tide mark on the shore approximate in coloring to the land plants — that is, their prevailing color is green. Farther down the beach or rocks, covered at high tide and laid bare at low tide, we find the plants of the prevailing olive-brown tint.

Underneath these and sheltered by them red forms are found; and these, too, may be discerned in rock-pools at the bottom. At the lowest tide-level and extending into the shallow sea we notice multitudes of brown seaweeds with red ones intermingled with them, but it is only in the greatest depths which support plant life at all that the red members are found by themselves.

There is a limit to the depth at which sea plants are enabled to thrive. They become fewer and fewer after twenty fathoms (120 feet), and it is very unusual to find them beyond a depth of fifty fathoms (300 feet).

What determines the depth at which sea plants can grow? Doubtless it is a question of the penetration of sunlight through the water, light being necessary for chlorophyll to perform its all-important functions in connection with processes of nutrition. But the sea is not in utter darkness in the daytime until we reach a depth of some seven hundred fathoms or less, and it might therefore be supposed that plants would flourish up, or rather down, to that depth. As a matter of fact, however, they do not.

There is another intervening factor besides that of the mere penetration of light. There is a qualitative change as well as a quantitative change in the light which passes down through the water, and this is the further explanation. Light is composed of various rays, as we know, and the different rays have different functions and properties. Some are more active than others in the work of assisting chlorophyll in its function, and, curiously enough, it is precisely these which are first intercepted by the sea-water. The only rays of light which reach the greater depths are the blue rays and the green rays. This would suggest that the additional pigments found in sea plants, which we have named above, have been evolved as additions to chlorophyll to make up for the qualitative change in light which takes place in these depths.

Possibly they assist the chlorophyll to make use of what light reaches the plant, rendering it more easily affected by light. Or perhaps they afford some kind of protective influence against the excess of the

blue rays which penetrate. The second view is regarded as the more probable by Mr. George Murray in his excellent book on the "Study of Seaweeds", to which we owe many of the facts here stated. Similar protective functions are ascribed to pigments in certain land plants, which supports this view.

It is true that minute and other plants have been obtained from great depths occasionally, but they do not live there under normal conditions. Probably they have been carried down by currents. So that

Sea temperature does not vary in anything like such great degree as does that of the air on land, neither diurnally nor seasonally. It is much more constant than we are apt to suppose, the changes we appear to feel in it, when bathing, for example, being much more due to the changes in the air we are in than to changes in the temperature of the water. Thus we often imagine the sea-water is very warm at night, tested, it may be, by dipping the hand over the side of the boat. It is the night air which has become colder, and

SCARLET PLOCANIUM, ONE OF THE MOST ABUNDANT OF THE RED DIVISION OF SEAWEEDS

we have the outstanding point that color, which is of no value in classifying land plants, is correlated with other characters in sea plants; and we need not be surprised at that, when we remember that in the sea color is of immense importance in connection with the performance of the nutritive functions. Light, then, chiefly determines the depths at which sea plants live.

The second great factor in the life of sea plants is the temperature of the water, and it is this factor which is responsible for the geographical distribution of sea plants.

gives us that impression. Living, therefore, in a fairly constant temperature, sea plants naturally are very susceptible to changes in that temperature. They are not accustomed to them. Hence the necessity of careful regulation of the temperature in aquaria if the plants are to flourish.

Other factors, too, play a part in the life in the sea. Notable amongst these are the degree of the saltness of the water, the kind of bottom on which the plants are growing, and the amount of tidal variation in any

given spot. So sensitive are seaweeds to temperature changes that it is difficult to transfer those from great depths to artificial surroundings, especially in summer. They should be packed in ice, and must have a cool place to grow in, where direct sunlight cannot penetrate. They resent quick changes of water and exposure to air.

In order to really study their growth with accuracy they must be suspended in the sea at their natural respective depths, and anchored in some convenient manner. The salinity of the water has not so great an adverse effect as has variation in salinity, as may be observed in estuaries and

BRITISH CORALLINE ON THE SHELL OF A LIVING LIMPET

places where fresh water is constantly arriving in varied amount according to the rainfall.

Mr. George Murray quotes a very interesting case bearing upon this point. "A canal connects the sea with a lake that receives almost all the fresh water of Mecklenburg, and many species of seaweeds grow in this lake at places where the salinity is almost nil; while almost all are absent from the canal, which conveys sometimes salt water and sometimes fresh." Thus we see that it is the alterations in salinity rather than the degree of salinity which adversely affect the growth of the sea flora.

Among the primary factors in the distribution of sea plants in space must be reckoned the great and small ocean currents, which act also as agents of seed dispersal for land plants, as we have previously noted. But in the land plants, it will be remembered, we found many curious and varied adaptations to enable them to take advantage of ocean and other water currents as agents of dispersal. In the case of the sea plants there is no need for these special adaptive arrangements. The ocean currents seem to control what may be termed the climate of the sea-water, much as high ranges of mountains affect land plants. We often find the flora on two sides of a mountain range differing widely, and in similar manner the sea flora on the two sides of a continent exhibits wide variations from the effect of currents. Thus the West Coast of Africa is washed by a cold current coming up from the south, whereas the East Coast is under the influence of a warm Mozambique current from the north, and the species of sea plants vary accordingly. The flora of the different portions of the Gulf Stream is similarly varied, exhibiting the plants of the temperate region in the Shetland Islands and the Arctic flora of Cape Farewell, both these being on the same parallel, but the latter influenced by the cold current from the east of Greenland.

The analogy between plant distribution on land and in sea may be further illustrated by observing how the vastly increased means of communication in the modern world plays a part. This is, of course, very clear in the case of land plants, but it acts, too, for those of the sea. Iron ships carry great numbers of seaweeds from place to place, more so than did the old wooden vessels, whose copper bottoms protected them. True, the great mass of sea-water is continuous, and there is nothing of a physical nature to offer insurmountable barriers to dispersal, but the varying temperatures of seas which communicate with each other determine the exact species that will flourish in each. Lastly, in this connection, it may be noted that the species which the various oceans

have in common are, as perhaps might be expected, those of the smaller type rather than the great sea plants.

A very interesting fact is observed if the flora of the two polar regions be compared with each other. There are no less than fifty-four species at least — perhaps more — which are common to the Arctic and Antarctic waters, but which do not occur in the intervening tropics, and these plants must have been divided from each other by this intervening mass of warmer water from time immemorial — indeed, ever since the world has known the meaning of climatic differences. Let us inquire how this striking resemblance comes about.

PART OF A FROND OF BRITISH CORALLINE, SHOWING STONY STRUCTURE

Sir John Murray, in the reports of the *Challenger* expedition, puts forward the following theory on the point. "In Carboniferous times the surface temperature of the sea could not well have been less than about 70° F., and the same temperature and the same marine fauna prevailed from equator to poles, the temperature not being higher at the equator. In early Mesozoic times cooling at the poles and differentiation into zones of climate appear to have commenced, and temperature conditions did not afterwards admit of coral reefs in the polar area, but the colder, and hence denser, water that in consequence descended to the great depths of the ocean carried with it a large supply of oxygen, and life in the deep sea became possible for the first time. There have been many speculations as to how a nearly uniform temperature could have been brought about in sea-water over the whole surface of the earth in early geological ages, as well as to how sufficient light could have been present at the poles to permit of the luxuriant vegetation that once flourished in those regions. The explanation that appears the most satisfactory is the one which attributes these conditions to the very much greater size of the sun in the early stages of the earth's history — an idea first introduced into geological speculations by Blandet, who likewise discussed the relations of Arctic and Antarctic faunas — together with the greater amount of aqueous vapor in the atmosphere and the greater mass of the atmosphere."

A comparison between the lives of land and sea plants is very instructive, and we may pursue it a little further. It will help us to fix in our minds some of the great general biological principles it has been the object of these chapters to convey. We learned in our early study how dependent is the animal world upon the vegetable for food supply, inasmuch as it is the plant alone which can convert the inorganic matter into the organic. Hence the enormous bulk of land plants. Now apply this to the conditions of sea plant and animal life, and a very interesting point emerges. The vegetables of the sea, so to speak, are only obvious along the coasts, and even here. as we have seen, the plants do not grow to any great depths. This somewhat scanty supply could not

by any chance be adequate to maintain the enormous animal population of the sea, creatures which, for one thing, live far out at sea on the surface of the water, and, for another thing, also descend considerable distances out of the realm of sunlight. How is this disparity made up?

FORKED DICTYOTA

The answer is that it comes from the plankton or floating population of the sea, a population consisting of an enormous bulk of extremely minute plants and animals, so minute that only the microscope reveals their nature, and only visible to the unaided eye when massed together in uncountable millions. Some of the more interesting and better-known members of this population must be mentioned, for they are among the most fascinating of the sea plants. First we have the *Diatomaceæ*, an immense group which numbers in it no less than some ten thousand different species inhabiting all the known waters of the earth. Diatoms are common on stones and the bottoms of fresh-water ponds and streams as well as in the sea. They have been studied in greater detail than most, partly on account of their wide distribution, and also, no doubt, on account of their fascination and beauty.

FEATHERY PTILOTA — A RED ALGA

The diatoms are microscopic plants consisting of a single cell in each individual, the envelope of the cell being impregnated with silicious matter. Each individual has two shells termed *valves*, which overlap each other. The arrangement is like that of a box with an overlapping lid. The plants are colored with chlorophyll and an additional brownish pigment, and many species are capable of movement. They reproduce themselves in a peculiar manner, by dividing into a successive number of partitions, each new generation being therefore smaller than the one preceding. Then they undergo a kind of spore formation, and the original size of the individual is regained. Like many microscopic forms of life, they sometimes adhere to each other in chains or masses, in the latter case being embedded in a viscous substance. Others live as independent unicellular plants. In the mass they look brown. The great beauty they present is especially due to the marvelous variety of the sculpturing which is seen on the shells, or valves.

Their movements, which are rapid, are always in the direction of backwards and forwards along the plane of their own long axis. It does not suggest the motion of an absolutely free organism swimming in the watery medium. It takes place along the surface of whatever the diatom is resting upon, and is possibly due to the

protrusion of cilia. "That these movements take place with considerable relative force is shown," says Mr. George Murray, "by the observation of Donkin, who saw one species push away another at least six times its size, while other observers state that they have seen this greatly exceeded. The speed of the movement when compared with the rapid dartings of ciliated organisms is slow. The Rev. William Smith estimated the rate at about four hundred times a diatom's length in the space of three minutes."

A DIATOM, OR WATER-PLANT, MAGNIFIED FROM THE SIZE OF A PIN-POINT

Although diatoms occur in untold numbers in the sea, and in all seas, they are most numerous in the chilly seas of the northern and southern oceans. When adherent in masses they form a "scum" on the water that has been examined when brought in by surface tow-nets. The individuals composing this mass of scum gradually die, and the silicious shells sink to the bottom of the sea, where they form the famous diatomaceous ooze. Ordinary fish, shell-fish, and the lobster and shrimp group, utilize diatoms as food, and there is no doubt that they constitute the most abundant vegetable food in sea-water. They are preserved as fossils from tertian and quarternary times, and find a use in

modern life in the well-known tripoli powder which consists of their shells. They are utilized in making dynamite, and in polishing mixtures.

Leaving these fascinating microscopic forms of plant life, we may look for a moment at some more familiar seaweeds, such as may be found upon our own shores almost anywhere. The seaweeds that can be most easily seen are naturally those which grow about the level of the tide when high, and amongst the most common of these are large, flat forms known as the *Ulvaceæ*, a group of the green algæ. The mass of the plant, or the thallus, is irregular in outline, sometimes branched, and may be hollow, the space being between one or more layers of cells which have separated in growth. They are found all over the world, and even in fresh water. They, above all seaweeds, are responsible for the fouling of the bottoms of ships, producing what is termed "grass" by sea-going men.

MAGNIFIED TIP OF A FROND OF FEATHERY PTILOTA, A RED ALGA, SHOWING FRUITS ON ITS MARGIN

Another group, the *Fucaceæ*, of the brown algæ occur in all seas, but the species differ according to the temperature of their distribution. The thallus here is not so generalized as in some, and may present a distinct differentiation into such parts as stem, leaf and root, if these terms are permissible in connection with sea-weeds. The layers of cells resemble those of land plants in suggesting an outer layer of epidermis, with parenchyma beneath, and a central portion which is like that of vascular bundles. The central strand passes along the plant into the stalk of the leaf, where it divides. The whole plant is attached at its root by a disc or sucker, or by special fibers still more suggestive of roots, and especially like the roots of parasitic plants. In some species special branches are set apart to carry the reproductive cells, or these may be on the ends of the leaves, or they may be dispersed over the mass of the plant. Where sexual cells are formed they are set free at ebb-tide as the result, in all probability, of the loss of water pressure, the cells uniting in the water when oncemorefloated by the returning tide. Other forms are hermaphrodite.

Another group distributed in all seas, but especially in the North Atlantic, are the *Chordariaceæ*, which may be recognized from their slimy mass. Usually they are in the form of strands, covered with filaments.

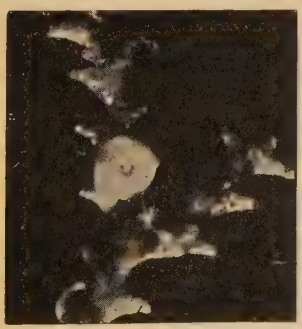
Next we may note the widespread *Rhodophyceæ*, or red algæ, with varying shapes and sizes, ranging in color from bright red to dull brown, and in appearance from filaments to flat bodies. One of them produces the well-known Ceylon moss from which is prepared a substance termed "agar-agar", which is of immense value

TANGLE OR FINGERED LAMINARIA LEFT EXPOSED UPON THE ROCKY SURFACE OF THE SEA-SHORE BY THE RECEDING TIDE

to the bacteriologist. It has the property of solidifying liquids, in the same way as does gelatine, but agar-agar requires a far higher temperature than does gelatine to melt it, and hence can be utilized for growing such microörganisms as grow best at the temperature of the mammalian blood. A peculiar family of this group are the *Corallineæ*, easily recognized from the fact that the thallus is encrusted with lime salts, producing masses like stones. Some species grow along with true coral, and act as a cement by joining the corals together. Naturally they are very brittle. Several species may be found on American shores.

A remarkable group of sea plants called the Sea Grass must not be omitted. They resemble ordinary land plants much more closely than those already considered, especially in the fact that they have stems which dip down into the mud and are fixed by definite root fibers. From the stems there arise a number of extremely long, ribbon-like leaves, narrow and almost erect, being kept in position by the water. The grass wracks are found growing in large masses between the high and low tide levels. Many of the sea wracks are brown and leathery, and may be contracted into a stalk below, by means of which they attach themselves, widening out above into flat, leaf-like structures. Such are the Laminarias, brown algæ of the North Sea. It may be noted, in passing, that no matter how like a land plant a sea plant may be, it never develops true woody tissue, no matter what its size.

The sea plant remains stationary in its watery depths, or is swayed to and fro by the currents around it, but these do not tend to damage it, and no special contrivances are necessary to strengthen the plant, such as those we discussed in connection with trees of the forest. It is for this reason that aquatic plants, when brought into the open air, quickly collapse, their moisture evaporates readily, and,



SHELL ON SEA-FIR

FRUIT ON KNOTTED WRACK

SQUARE-TOPPED SEA-MAT

having no hard framework, their characteristic shape — and with it their beauty — disappears. Their erect attitude in the water is assisted by the presence of air spaces in their tissues. The sea-wracks do not shrivel up between low and high tides; they simply lie flat until the water returns, but they can only stand this exposure for a limited time. The largest sea-wracks may grow to immense sizes, as much as from 300 to 900 feet in length, a prodigious growth comparable to the largest trees. It must be remembered, however, that these do not grow erect to this height, but grow at an angle towards the surface, taking the direction of the prevailing current.

CARRAGEEN, OR IRISH MOSS

The careful reader, who has followed us through our study of the plant population, alike of the earth's surface and the ocean's depths, will, it is to be hoped, have realized that the great lesson to be learned, from a rapid glance at the main points of an enormous subject such as this, is that plant life, like all organic life, has developed by natural selection and the survival of the fittest, until there have been evolved marvelous adaptations for specialization of function of which in the course of our studies we have seen so many examples. No such study has been effective if it fails to impress us with the wonders of creation and the beauty spread about us in such profusion by the Creator.

ROCKS ON THE COAST COVERED WITH BLADDER AND OTHER SEA-WRACKS

ASTRONOMERS V

JAMES EDWARD KEELER — ASTROPHYSICIST AND STUDENT OF THE NEBULÆ
JOHANN KEPLER — DISCOVERER OF THE UNITY IN THE SOLAR SYSTEM
PIERRE SIMON LAPLACE — THE DIVINER OF CELESTIAL MECHANICS
WILLIAM LASSELL — A GREAT DISCOVERER OF SATELLITES
JEAN JOSEPH LEVERRIER — A DISCOVERER OF NEPTUNE
SIR NORMAN LOCKYER — THE AUTHOR OF THE METEORIC THEORY
PERCIVAL LOWELL — THE STUDENT OF MARS

JAMES EDWARD KEELER
Astrophysicist and Student of the Nebulæ

JAMES EDWARD KEELER, an American astronomer and astrophysicist, director of the Lick Observatory and renowned for his studies of the nebulæ and determination of the nature of Saturn's rings, was born at La Salle, Illinois, on September 10, 1857. His father, William F. Keeler, was one of the officers on the U. S. S. *Monitor* at the time of its fight with the *Merrimac*, and his mother, a daughter of Henry Dutton, a former governor of Connecticut and dean of the Yale Law School. From his father he inherited mechanical tastes which stood him in good stead in his later astronomical work, when he was called up to arrange and devise large instruments of high precision. His early life was spent in the South, at Mayport, Florida, and it was here that he became interested in astronomy, buying for himself lenses for a two-inch telescope which he mounted when but seventeen years of age. The observations made with this telescope were carefully recorded and in 1877 he built for himself a meridian instrument. A series of important observations and a systematic method of procedure now served to remove him entirely from the ranks of amateurs and, accordingly, making up his mind to devote himself to astronomy, he entered the Johns Hopkins University. In 1878 he accompanied the naval observational eclipse party to Center City, California, as a junior assistant. After further studies at Johns Hopkins in 1881 he went to the Allegheny Observatory at Pittsburgh to become assistant to Professor S. P. Langley, who at that time was engaged in studies with the polometer. He accompanied this celebrated scientist to Mount Whitney, California, on his expedition to determine the solar constant and remained at the Allegheny Observatory until 1883. During a trip abroad now undertaken he was able to study with Quincke at Heidelberg and von Helmholtz at Berlin, and then returned to the Allegheny Observatory, where he remained from June, 1884, to June, 1886.

At this time the construction of the Lick Observatory on Mount Hamilton, California, was under way and Keeler was appointed assistant to the trustees. His first astronomical work was to establish the time service to the new observatory. When the observatory itself was completed and transferred to the regents of the University of California, on June 1, 1888, he was appointed astronomer. The original staff of this remarkable institution consisted of a group of notable astronomers — Holden, Burnham, Schaeberle, Keeler and Barnard, and assistant astronomer Hill — all men who were destined to make their impress on astronomical science, and who were well qualified to undertake the work of observation with the extraordinary facilities which the new observatory provided. In the assignment of duties Keeler was placed in charge of the spectroscopic work, and a large star spectroscope, built largely from his own designs, was placed at his disposal. With this in-

strument, at the time quite the best of its kind for visual observation, Keeler observed Saturn's rings and Uranus with special reference to their atmospheres. Other work was a study of the bright and dark lines in the spectra of Gamma Cassiopeiæ and Beta Lyræ, the spectra of the Orion nebula and the planetary nebulæ. In these early days he also determined the color curve of the 36-inch equatorial telescope.

Keeler's observations on the velocity in the line of sight of these nebulæ marked a distinct epoch in visual spectroscopy. He was able to establish the fact that the

Photo Sperber

JAMES E. KEELER

velocities of the nebulæ in their motions through space were of the same order of magnitude as the velocities of the stars. Using the great 36-inch equatorial telescope, he further observed the planetary nebula and their stellar nuclei, making an extensive series of both visual and spectroscopic observations. This great instrument in his hands was able to yield wonderful results, among which were a series of splendid drawings of the planets Saturn, Jupiter and Mars.

Professor Keeler was in charge of the Lick Observatory solar eclipse expedition of January 1, 1889. Called to succeed Langley as director of the Allegheny Observatory and professor of astrophysics in the Western University of Pennsylvania, Keeler resigned from the Lick Observatory staff, and again took up his work in Pittsburgh. Here he made a new spectroscope with many improvements, with which he studied the Orion nebula and the stars immersed in it. He was able to establish the important fact that the nebulæ and the stars were closely related in physical condition. In 1895, during an observation of Saturn's rings, he proved that they were merely a cluster of meteorites or myriads of little moons. This discovery of the insolidity of Saturn's rings in its importance has never been surpassed in the entire field of astronomy, and has been referred to as the greatest astronomical observation ever made. Already mathematical astronomers had speculated as to the rings of Saturn, but now the theory was removed from the realms of mathematical conjecture and their meteoric nature was made the subject of direct and positive observation. Keeler was able to prove spectrographically by employing the Doppler-Fizeau principle that every point in the ring system was moving with the velocity which a moon would have if studied at that distance from the planet. His main continued piece of work at the Allegheny Observatory was on the spectra of the third (Secchi) type stars.

On March 8, 1898, Keeler was appointed director of the Lick Observatory to which he returned, not only with an enhanced reputation but with an enthusiasm and knowledge of astronomical and spectroscopic work which was destined to bring important results. On assuming direction he made no special changes in the program of the staff, but for his own special efforts took the Crossley reflector, a telescope with an excellent mirror of three feet aperture, but supplied with a mounting that did not lend itself readily to the work then in hand. It had been presented to the Observatory by an English friend but so far had not been found particularly useful. This instrument Keeler mastered, so improving and adapting it that he was able to make an extraordinary series of nebular photographs which were contin-

ued for a number of years at the Observatory by Perrine, and were a chief source of our knowledge in this field. With this Crossley reflector, one of the most powerful photographic instruments then available, Keeler was able to check up the old observations and make many new ones. He discovered that of some 120,000 nebulæ strewn over the heavens and rendered visible by this telescope, fully half were distinctly spiral in form and there were not as many irregular nebulæ and nebulæ without form as had been anticipated. This conclusion was of special application to the discussion of the nebular hypothesis, and was a distinct contribution to the material available in considering the origin and development of the stellar universe.

On the instrumental side the photographic studies of the nebula made by Keeler with the Crossley reflector demonstrated the importance of this type of instrument in a field where such studies were particularly welcome. The arrangement of the instrument and its general adaptation to this purpose was due to Keeler. His health at this time was already beginning to fail under the strain of overwork, and he died August 12, 1900.

In 1893 Keeler had received the degree of Sc.D. from the University of California. In 1898 the American Academy of Arts and Sciences awarded him the Rumford medal, and in the following year bestowed on him the Henry Draper medal. In April, 1900, he was elected a member of the National Academy of Sciences, while he also enjoyed the honor of being an associate of the American Academy of Arts and Sciences, a fellow and foreign associate of the Royal Astronomical Society, a fellow of the American Association for the Advancement of Science, an officer of the Astronomical and Astrophysical Society of America, an honorary member of the Toronto Astronomical and Astrophysical Society, and president of the Astronomical Society of the Pacific. He was one of the editors of the *Astrophysical Journal*, to which he often contributed, as well as to the *Memoirs* of the Royal Astronomical Society, and he wrote "Spectroscopic Observations of Nebulæ" (1894).

JOHANN KEPLER

Discoverer of the Unity of the Solar System

THE vast labors of Tycho Brahe, one of the greatest astronomical observers who ever lived, had amassed an enormous wealth of detail, gained by systematic and unwearied observation. But from the speculative point of view, Tycho's work had the single effect of depriving men of all their formerly accepted theories of the construction of the universe. The false views had been shattered, and huge

JOHANN KEPLER

materials had been collected towards the building of true science. But Tycho, who rejected the Copernican theory, was not the man to conceive the architectural design which was soon to unite and give meaning to all his observations. Yet the man, though he knew it not, was there in the person of one of his assistants. There has rarely been a happier concurrence of circumstances than that which brought together the two great minds of Tycho Brahe and Johann Kepler. The former, who has been styled the "king of astronomers", was a wonder-

ful observer, but Kepler, who possessed one of the greatest mathematical minds of any age, could do little or nothing in that line. It was partly due to physical infirmity. Kepler was a weakly, ill-nourished man, and his eyes were easily fatigued. It is pleasant to remember that Kepler, who struggled through all his years against poverty, anxiety and ill-health, was generously assisted by the princely Tycho, to whom, in his turn, Kepler always gave most generous honor.

Born at Weil in Würtemburg, on December 21, 1571, Johann Kepler was the son of an army officer who was reduced to desperate poverty through overgenerosity in becoming surety for a friend. Seeking a way out of his difficulties, the father took to keeping a tavern, and at the age of nine years the immortal Johann was removed from school in order to serve as a potboy. Fortunately, after three years of this unsuitable life, the studious, delicate lad was received into a monastery school, whence he proceeded, in 1589, to the University of Tübingen. Here he studied mathematics, and was introduced to the Copernican theory of the solar system. Its truth broke upon his mind like a new life, and henceforth he had no desire so constant or so keen as the enthusiastic devotion to this novel and wonderful vision of the heavens. He was graduated with honors and appointed, in 1594, to a very poorly paid mathematical position in Styria. Two years later his first work was published in the form of a very lucid and closely reasoned argument in support of the Copernican theory, which was at that time a quite debatable matter. In this work he attacked the problem of his life — the harmonious unity which, as he was convinced, bound together all the members of the solar system. It was entitled the "*Mysterium Cosmographicum*". Kepler sought herein to find a law of relation between the number of the planets, their periods of revolution and their relative distances from the sun. Having tried in vain to discover a simple ratio, and then a trigonometrical function, which should explain these distances, he conceived a peculiar hypothesis of five regular solid spheres separating the six spheres of the planetary orbits, and worked out this conjecture at great length and with much fantastic reasoning. He was satisfied, so far, with his extravagant theory, but was still not content with the calculations which Copernicus had given with regard to the mean distances and eccentricities of the planets, and desired to obtain more reliable figures in order that he might give a more complete demonstration to his novel system. As everyone knew, the only living man possessed of the necessary observations was the great Tycho Brahe, who had at that time a reputation which it is impossible to overestimate. To him, therefore, Kepler appealed. Tycho replied in the most friendly way with an invitation to come and join him and make unrestricted use of all his material. In the year 1600, therefore, Kepler became Tycho's guest at the castle of Benatsky, and there began his long and fruitful researches into the problem of the orbit of the planet Mars.

In the early days of 1601 he became Tycho's assistant, and on the death of the great man, in October of the same year, was appointed his successor as imperial mathematician to the Emperor Rudolph at a good salary, which was, however, somewhat difficult to get out of the treasury. The study of Mars, which he had already begun, occupied Kepler for four years more; but finally, after countless wrong guesses and an enormous amount of labor, the solution was attained. In 1602 he had come to the conclusion that the orbit was oval in form, but soon perceived that this hypothesis did not satisfy all the data which had been observed. In December, 1604, he wrote to his friend David Fabricius, the astronomer, announcing that he had ascertained the orbit to be a perfect ellipse.

This discovery marked a new epoch in astronomy. It was the abandonment of the principle of circular motion, which had previously been taken for granted as universal in all heavenly bodies. From the discovery of this fact, Kepler proceeded with characteristic enthusiasm to the endeavor to account for it. He

believed that a constantly acting force was necessary to maintain a constant motion, because the principle of inertia was as yet unrealized. He supposed that this force emanated from the sun, and moved round with the sun in a circular stream, and that the diminishing velocity of the outer planets was due to the weakening of this force with increasing distance from the sun. He explained the elliptical form of planetary orbits as due to magnetism. "The planets," he said, "are magnets, and are driven round by the sun by magnetic force, but the sun alone is alive." The idea of gravity as accounting for the motions of the celestial bodies never occurred to him at all.

Kepler's studies of the orbital movement of Mars revealed, however, his two first "laws", which are of primary importance. They are as follows: first, planets move in ellipses, with the sun in one focus of the ellipse; and, secondly, the *radius vector*, or the line joining the sun and the planet, sweeps over equal areas in equal times. These laws were published in his second book, which contained the whole statement of his theory of planetary motion, and was called "*De Motibus Stellæ Martis*". The title, however, gave the credit of the work to Tycho's observations, for it continued, "*Ex observationibus G. V. Tychonis Brahe*". This illustrious book ranks, with the "*De Revolutionibus*" of Copernicus and the "*Principia*" of Newton, above all other astronomical works. Its manuscript was completed in 1607, and the book was published in 1609, in which year Galileo discovered the telescope.

Unfortunately for Kepler, the Emperor Rudolph died in 1612, and the imperial astronomer lost all hope of retrieving the arrears of his salary, and of obtaining any additional help which he had asked in order to investigate the motions of the other planets. This misfortune was followed by a series of domestic afflictions. His three children took smallpox, from which only two recovered, and at the same time his wife died of a nervous affection. Greatly disheartened, Kepler resigned his imperial appointment, and went with his two little children to Linz, where he undertook the duties of "provincial mathematician". He fell into great poverty, and was compelled to supplement his meager salary by the practice of astrology although he held this superstition in the contempt which it deserved.

At Linz, Kepler set to work on a very ambitious treatise, which was to be called "Hipparchus", but was never completed. He turned from this to a more elementary work, "*Epitome Astronomiæ Copernicanæ*", which was published in the years 1618 to 1621. This book deals very fully with the movements of the moon, and applies the laws which had been discovered for Mars to the orbits of all the planets.

Kepler's most attractive work is undoubtedly the book "On Celestial Harmonies", published in 1619, and dedicated to King James of England. Herein he completed his theory of cosmic harmony, which had already been foreshadowed in the "*Mysterium Cosmographicum*". It was in pursuit of this sublime idea that he had sought the assistance of Tycho. The corrected observations which he then obtained failed to supply him with a harmony in the distances of the planets, so he had to seek it, and ultimately found it, in their motions. It is notable that his true scientific faith insisted on harmony, and rejected or abandoned all that was not harmony. The book is full of very fantastic speculations, but Kepler's unerring devotion to the harmony of the universe, and his insatiable thirst to arrive at its source, were responsible for the prodigious discoveries by which he rejuvenated astronomical science and freed the Copernican system from many of the older erroneous views from which it had not yet been disentangled. In this book on "Celestial Harmonies" was published the third of Kepler's laws, "That the square of the time of revolution of each planet is proportional to the cube of its mean distance from the sun."

A less important but even more laborious work appeared in 1627. This consisted of new planetary tables, the "*Tabulæ Rudolphinæ*", whose compilation had taken up years of arduous calculation.

On the title page of this book Kepler states — and the history of astronomy fully indorses his claim — that its pages constitute "the restoration of astronomy, conceived and carried out by the Phœnix of astronomers, Tycho". It was altogether characteristic of Johann Kepler that he gave all the honor to another and sought nothing for himself.

Kepler's ideas of the vast system of stars beyond the solar system were not much in advance of those which were at that time generally accepted. He believed that the fixed stars were set in a solid sphere, and that the center of this sphere was our sun. This starry sphere, or shell, was two German miles in thickness, and the Milky Way was spangled on its inner surface. Within this all-inclosing shell was the "ethereal air", the medium through which the planets move. The comets consisted of condensations of this air which, impelled by a force from the sun, moved more or less like living creatures through the ether until they became dissolved by the heat of the sun.

Kepler died on November 15, 1630. His labors and his insight had revealed the solar system in all its simplicity, and had for the first time linked together all its members by the law relating their distances to their periods of revolution.

PIERRE SIMON LAPLACE
The Diviner of Celestial Mechanics

THIS "titanic geometer", this "Newton of France", as he has often been styled, was the greatest of the band of brilliant mathematicians who completed what Sir Isaac Newton had begun, and traced out all the workings of the law of gravitation in our solar system. The corner-stone of this elucidation was Laplace's subtle study of the causes of the acceleration in the movement of the moon, which he published in a paper of the year 1787. But the "*Mécanique céleste*" (mechanism of the heavens) was the appropriate title of the great work in which Laplace finally exhibited the gravitational relations of sun, planets and satellites. Miss Agnes Clerke, the historian of astronomy, says of this work that "as a mere machine, the solar system, so far as it was then known, was found to be complete and intelligible in all its parts; and in the '*Mécanique céleste*' its mechanical perfections were displayed under a form of majestic unity which fitly commemorated the successive triumphs of analytical genius over problems among the most arduous ever dealt with by the mind of man."

Pierre Simon Laplace was born at Beaumont-en-Auge in Normandy on March 28, 1749. He was the son of a small farmer, and at an early age began to earn his living as a teacher of mathematics in his native place. Probably the chief motive in the youth of Laplace, as in his later life, was a consuming ambition, which made an obscure provincial position intolerable to him. His opportunity of a wider sphere came in 1767, when he secured the patronage of D'Alembert, himself an able mathematician, by means of a letter dealing ingeniously with certain problems of mechanics. This fortunate introduction brought Laplace an appointment as professor of mathematics in the École Militaire of Paris; and from this time forward his career was one of almost uninterrupted success, achieved not always by the most strictly honorable means, yet certainly due to his extraordinary mathematical ability.

His first remarkable discovery was made with Lagrange in working out the explanation of the "long inequality" of Jupiter and Saturn, published in three papers from 1784 to 1786. His attention having been thus concentrated on the giant planet, Laplace went on to solve the riddle of Saturn's satellites, and discovered that the speed of the first satellite, added to twice the speed of the second, is equal to the speed of the third — a formula sometimes referred to as Laplace's law. The discovery of the acceleration of the moon's motion followed in 1787, and created a great sensation in the scientific world. Laplace had ascertained that the eccentricity of the earth's orbit is becoming gradually but very slightly less; and that the effect of this change is slightly to increase the mean distance of the earth from the sun. This increased distance from

the sun results in a corresponding decrease of solar gravitational influence on the moon. And since the effect of the sun's gravitative pull is to enlarge the moon's orbit, any decrease in that pull results in a slight contraction of the moon's orbit, and consequently an increase in her velocity. Laplace's estimate of the rate of acceleration was not, however, altogether correct, and has been revised by later students.

Laplace's monumental work, the "*Mécanique céleste*", occupied most of his time between 1799 and 1825. In these labors he borrowed very freely from the works of predecessors and contemporaries, and took no trouble to acknowledge his literary and scientific indebtedness. The result is a singularly complete presentation of the entire theory. The book gains immensely in effect by this unhesitating adoption of all that had been done before; it gives an impression as if all astronomical knowledge had sprung complete from a single brain. This rather unscrupulous method would be regarded in our day as intolerable; but it must be remembered that standards in these matters were much more lax a hundred years ago.

A more popular but hardly less ingenious work dated from 1796. It was called "The Exposition of the System of the World", and is chiefly remarkable because it contained the first pronouncement of the "nebular hypothesis", which has played so great a part in later astronomical speculation. The germ of the great idea is present only in very embryonic form; indeed, it is suggested merely in a note appended to the text, but Laplace leaves us in no doubt as to the value which he put upon his novel hypothesis. He was persuaded that he had penetrated into the central mystery of stellar evolution, yet advanced his hypothesis, as he said, "with that distrust which everything ought to inspire that is not a result of observation or of calculation".

Laplace's earliest form of the nebular hypothesis represented the sun as already in existence, very much as it exists now. The sun was "surrounded with a vast, glowing atmosphere, extending into space out beyond the orbit of the farthest planet, and endowed with a slow rotary motion. As this atmosphere or nebula cooled, it contracted; and, as it contracted, its rotation, by a well-known mechanical law, became accelerated. At last a point arrived when centrifugal force at the equator increased beyond the power of gravity to control, and equilibrium was restored by the separation of a nebulous ring revolving in the same period as the generating mass. After a time, the ring broke up into fragments, all eventually reunited in a single revolving and rotating body. This was the first and farthest planet." Successive planets and their respective satellites were then formed in a similar manner. The theory, of course, received invaluable confirmation from the rings which surround the planet Saturn. The original germ of this nebular hypothesis came from Kant, who, though no astronomer, made two or three surprising guesses. Laplace, however, was the true originator of the theory as a serious explanation of the genesis of the solar system; and, although the idea has been much enlarged and modified, it remains as the basis of modern speculation into the method of cosmic evolution.

Until his death, Laplace continued his studies in mathematical astronomy, and published also papers in pure mathematics. The most important of the latter was his "Analytical Theory", which appeared in 1812, dealing with the profound subject of the theory of probabilities.

Laplace received all kinds of scientific honors, but hungered also for political advancement. Having secured Napoleon's favor, he became first a member of the Senate and then chancellor (1803), and was created an officer of the Legion of Honor and made a count. In 1814, however, when the tide had set against Napoleon, Laplace joined his opponents, and thus earned, in 1817, the title of marquis. His last years were passed at Arceuil, where he had a country place next to that of his friend Berthollet, and here he died on March 5, 1827.

Laplace's complete works have twice been published by the French government (7 vols. 1843–1847; 13 vols., beginning in 1878).

WILLIAM LASSELL
A Great Discoverer of Satellites

WILLIAM LASSELL was born at Bolton, in Lancashire, England, on June 18, 1779, and at the age of sixteen was apprenticed to a Liverpool merchant for seven years. Having long had a great interest in astronomy, but unable to afford to buy instruments, he set to work laboriously to make himself a telescope. In the end, this self-taught astronomer came to rank almost with Sir William Herschel for his skill in producing telescopic reflectors.

His first real opportunity came in 1825, when he was able to start in business on his own account as a brewer. He soon prospered, and, in 1840, was able to build an observatory at Starfield, near Liverpool, where he set up a Newtonian reflector of his own construction. It was of nine-inch aperture, and was mounted equatorially. But, like Herschel, Lassell was always keen to produce something better than was known before. He invented a machine for polishing telescopic mirrors, with which he was able to produce a wonderful fine surface, and in 1846 mounted in his own observatory a new telescope twenty feet in focal length, with a speculum two feet in diameter.

This also was mounted equatorially, and Lassell's reputation rests partly upon his application of equatorial mounting to the telescope. Ever since 1620, when Scheiner had attempted to connect a telescope with an axis directed to the pole, there had been many attempts at some device which should make it possible to keep a telescope pointed to the same regions of the heavens by counteracting the rotation of the earth.

Herschel had a most elaborate and complicated mechanism of pulleys and levers for moving his thirty-foot telescope, but this required several workmen to be always in attendance. The first really satisfactory arrangement was a clockwork device applied by Fraunhofer, at Dorpat, in 1824. But Lassell's improvement, according to the testimony of Sir John Herschel, marked a new epoch in the development of the reflecting telescope. Even the largest telescopes are now mounted equatorially.

Lassell was also an observer of wonderful ability. He described an eclipse of the sun in 1842, and in the following three years he was able, with his nine-inch telescope, to follow the movements of comets long after they had been lost to all other telescopes. The twenty-foot immediately yielded most important discoveries. In the first year in which it was set up, Lassell turned it upon the newly discovered planet Neptune, and discovered a satellite revolving in the retrograde direction. Two years later he discovered the eighth satellite of Saturn, Hyperion, at the same time as it was discovered by Bond at Harvard; and in 1851 he discovered two satellites of Uranus. Herschel had, in 1787, discovered the first two satellites of Uranus — Oberon and Titania — and in 1798 believed that he had discovered four more. But these four were really among Herschel's very rare optical illusions, as Lassell was able to prove.

In July, 1851, Lassell was in Sweden for the occasion of the total solar eclipse of that year, and during the following winter he was in Malta. In Malta he made many observations, with the twenty-foot, of the Orion nebula and of Saturn's ring. In 1861 he again went to Malta, to Valletta, taking with him a new instrument, which he had constructed in the interval. It was a magnificent reflector, thirty-seven feet in focal length, and with an aperture of four feet, its tube being composed of latticed iron, in order to provide against variations in temperature. With this instrument Lassell made a careful study of nebulæ, of many of which he made excellent drawings. He discovered six hundred nebulæ, and these he carefully catalogued. He remained on the island this time for four years.

After this second visit to Malta, Lassell moved his observatory to Maidenhead, on the Thames, where he lived for the rest of his life. He continued to observe, to publish his results in papers up to within a few years of the end of his life, and to attend the meetings of the Royal Astronomical Society, of which he served as president from 1870 to 1872, until his death, on October 5, 1880.

URBAIN JEAN JOSEPH LEVERRIER
A Discoverer of Neptune

URBAIN JEAN JOSEPH LEVERRIER, who predicted, simultaneously with John Couch Adams, the existence and position of the planet Neptune, was born at Saint-Lô, in Normandy, on March 11, 1811. His father was a minor government official. Leverrier was educated first at Saint-Lô, then at Caen, afterwards at the College of St. Louis, Paris, and finally at the Polytechnic School of Paris, where, in 1837, he became professor of astronomy. He had from this time been employed as an engineer in connection with the government tobacco monopoly, but he was altogether absorbed in mathematical studies of the movements of the planets, and soon gave evidence of astonishing mathematical abilities. Two papers, read before the Academy of Sciences in 1839, were the occasion of an introduction to Arago, and on the latter's advice he set out on the enormous task of solving the elusive problem of the erratic movements of the planet Uranus. His results appeared in a series of papers, of which the last appeared on August 31, 1846. The new planet was actually seen for the first time by Galle at Berlin on September 23 of the same year, and Leverrier achieved at one step a prodigious reputation throughout the scientific world.

The story of this wonderful mathematical discovery is told in our chapter on the planet Neptune. Unfortunately for the great French astronomer's reputation, its sensational interest has eclipsed his other labors, many of which were of equal if not of greater scientific value. Thus, he made most valuable researches into the sun's parallax, and fixed the orbit of several swarms of meteors.

Leverrier was appointed, in 1854, director of the Paris Observatory, in succession to Arago. He carried out certain very necessary reforms, but with such uncompromising ardor that his subordinates revolted, and in 1870 he was removed from his post for two years, to be reinstated, however, on the death of Delaunay, who had succeeded him. He died on September 23, 1877.

SIR NORMAN LOCKYER
The Author of the Meteoric Theory

JOSEPH NORMAN LOCKYER, one of the greatest spectroscopic students of the sun and stars, was born at Rugby on May 17, 1836. From an early age he gave his whole mind to astronomy, and his rapid progress may be judged from the fact that in 1860 he read a remarkable paper on Mars to the Royal Society, of which he was in the same year elected a fellow. The great possibilities of the spectroscope, in the study of astrophysics, had already attracted him to that field of science in which he was to win his renown. In 1866 he had devised a modification of the spectroscope for studying the flaming prominences of the sun in broad daylight, but the tardy makers were not able to deliver the instrument until October of 1868. In August of the same year Janssen had independently devised the same improvements, and the two astronomers, practically simultaneously, revealed the stupendous jets of blazing gas and vaporous metal which issue from our luminary. His name, together with that of Dr. Janssen, appears on a medal struck by the French government in 1872 to commemorate the discovery.

With the aid of the spectroscope, Sir Norman Lockyer made most elaborate investigations into the number of the chemical elements which are known to us on earth, and are to be found also in the sun. The inquiry was attended by great difficulty, owing to the doubtfulness of the spectroscopic record of certain elements; and of the thirty-three which he recognized some were afterwards found to be illusory. It is now fairly generally believed that certain substances exist in the sun in very different conditions from those in which they exist on earth, and that the spectra given by their light differs somewhat in the two cases.

In 1870 Sir Norman Lockyer was appointed lecturer on astronomy at the Normal School of Science at South Kensington, and received later an appointment also as professor of astronomical physics.

Sir Norman Lockyer's meteoric hypothesis, and also his spectroscopic work on

the sun, are dealt with fully in another chapter; and the facts there detailed need not be set forth here. His work on the "Meteoric Hypothesis" was published in 1887, and the theory was further elaborated in a book which appeared in 1897, entitled "The Sun's Place in Nature". The fundamental idea of all this work is that "all self-luminous bodies of the celestial space are composed either of swarms of meteorites or of masses of meteoric vapor produced by heat. The heat is brought about by the condensation of meteor swarms due to gravity, the vapor being finally condensed into a solid globe." He regards nebulæ as consisting of swarms of meteors, and as being the coolest of heavenly bodies, the temperature rising through various classes to the supremely hot Sirian type, and falling again to extinction in the dark stars. The hypothesis seeks to explain all the phenomena of the heavens by meteoric collision. The assumption that there exists a relation between the number of spots on the sun and the rainfall on the earth is due to his investigations.

Sir Norman Lockyer's many books on astronomical subjects include "Elementary Lessons in Astronomy" (1871); "Contributions to Solar Physics" (1873); "The Spectroscope and its Application" (1873); "Primer of Astronomy" (1874); "The Chemistry of the Sun" (1887); "The Meteoric Hypothesis" (1890); and "Inorganic Evolution" (1900). In 1871 he was Rede Lecturer at Cambridge; in 1874 Bakerian Lecturer to the Royal Society; and in 1874 he was awarded the Rumford medal by the latter. He was created K.C.B. in 1897. He died August 16, 1920.

PERCIVAL LOWELL
The Student of Mars

PERCIVAL LOWELL was born in Boston on March 13, 1855, of a family distinguished for the varied accomplishments of its members. The poet James Russell Lowell was cousin of the astronomer's father, and his younger brother, Abbott Lawrence Lowell, was a professor at Harvard University and afterward (1909) became its president in succession to Charles W. Eliot.

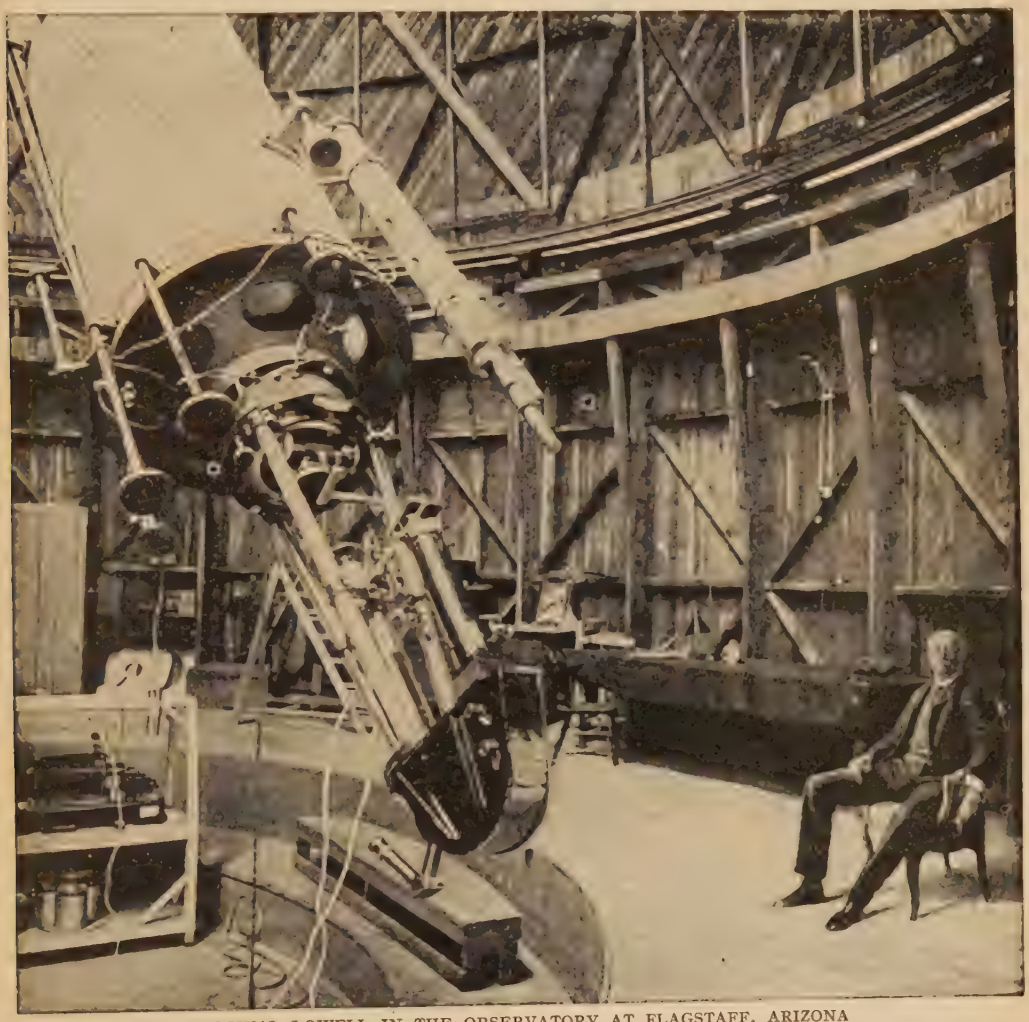
From childhood Lowell was greatly attracted by the mysteries of the heavens, and after graduating at Harvard in 1876, he began to write and lecture upon the nebular hypothesis, in which he was an ardent believer. Soon after leaving the university, however, Lowell spent some years in Japan and Korea. He had a warm regard for Japan and its people, and this feeling was fully reciprocated. He wrote several charming books about the country: "Chosön, the Land of the Morning Calm"; "The Soul of the Far East"; "Noto, an Unexplored Corner of Japan"; "Occult Japan, or the Way of the Gods", and in 1894 was counselor and foreign secretary to the Korean Special Commission to the United States.

Though Professor Lowell did much varied astronomical work, it is with the fascinating and tantalizing study of the planet Mars that his name is principally associated. The detailed study of the surface features of planets is, of course, a novelty within recent years, and has aroused enormous interest, perhaps because of the sinister hints which it affords with regard to the probable future of this world of ours. The Italian astronomer Schiaparelli opened up the subject of Mars, but Professor Lowell far surpassed his master.

In the early 'nineties, especially, there was great popular interest in Mars, owing to the discovery of the so-called "canals", which still constitute an open question of astronomy. There are so few men in the world who are competent to express an opinion at all in the matter, and their views are so hopelessly diverse, that we must be content to wait indefinitely before we shall know what the strange markings on Mars have to tell us. But skepticism is never so attractive as belief, and therefore Professor Lowell's speculations are extremely engaging. In the year 1894 he set up his wonderful observatory at Flagstaff, Arizona, with the express purpose of studying the planet Mars under the best possible conditions. Professor Lowell was convinced that the site is the most important consideration in planning an observatory, and that clear air is worth more than powerful lenses.

The great series of observations on Mars was begun in 1895, and by the end of that year Lowell was able to publish his views in a volume entitled "Mars". He followed Schiaparelli in regarding the "canals" as actual waterways, lined on each side by areas of vegetation due to irrigation, and believed with Professor Pickering that the lines which we see on the surface of the planet are these strips of fertile country, and not the waterways. The canals are supposed to distribute over the face of the planet the water which is supplied by the seasonal melting of the polar ice-caps.

Professor Lowell also observed Mercury and Venus with conspicuous success, discovering that, contrary to what was formerly supposed, each of these planets rotates once on its own axis during the period in which it travels once round the sun. He thus demonstrated that, as the moon turns always the same face to the earth, so both Venus and Mercury always turn the same face to the sun. Lowell was appointed, in 1902, non-resident professor of astronomy at the Massachusetts Institute of Technology, and his first course of brilliant lectures was published in the volume "The Solar System" (1903). His other astronomical books are "Mars and its Canals" (1906); "Mars as the Abode of Life" (1909); "The Evolution of Worlds" (1910); "The Genesis of Planets" (1916). He died in 1916.

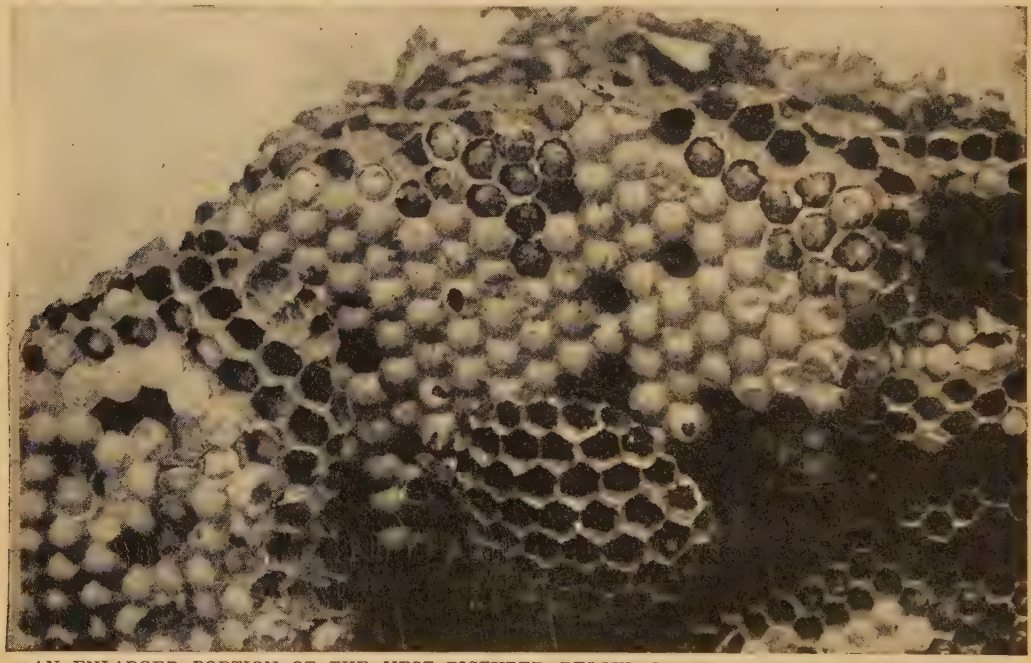


PERCIVAL LOWELL IN THE OBSERVATORY AT FLAGSTAFF, ARIZONA

THE WASP'S HOME INSIDE AND OUTSIDE

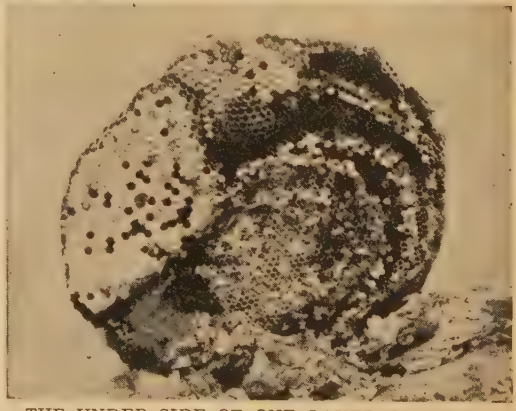
A NEST OF COMMON WASPS, PARTLY UNCOVERED

THE NEST REMOVED, SHOWING ENTRANCES



AN ENLARGED PORTION OF THE NEST PICTURED BELOW, SHOWING PUPÆ IN THEIR CELLS

THE TIERS OF CELL-LAYERS IN A NEST



THE UNDER SIDE OF ONE LAYER OF CELLS

ANTS, BEES AND WASPS

The Unapproached Marvels of Combination and Organization in the Insect World

SOME ROMANCES IN EARTH AND HIVE

IT is a striking and puzzling fact that to find in the animal world any sort of parallel to the life of civilized man we have to seek, not among the animals physically most highly organized, but among the insects. Nowhere in the kingdom of nature outside the family of man do we discover anything approaching the miracle of efficiency revealed in a common ant-hill or beehive. The feats of the beaver are impressive, the union of forces among certain of the baboons, the coöperative hunting of certain members of the dog tribe, are features not lightly to be dismissed; but, with all said, there is nothing in the animal world which really challenges comparison with the husbandry, harvesting, cattle-keeping, wars and slave-making of the ants; nothing even faintly rivaling the perfectly ordered system of the beehive.

By what process these insects have advanced to this extraordinary development of communal life we do not know. Whether existing conditions indicate the operation of reason, or whether they arise simply as the outcome of obedience to blind instinct in insects, we do not know. This is not the place in which to attempt an answer to the problem which the united efforts of men who have devoted lifetimes to the study have failed to solve. Auguste Forel holds that certain insects may — possibly do — possess sixth and seventh senses of which we know nothing; Sir John Lubbock believed with Darwin that they are gifted with a "dose of reason". On the other hand, there are the skeptics who sniff with incredulity at the results of careful experiments by such men, begun before some such critics were born, and continued after they had written their theories. Only by laborious personal investigation can the man who would grapple the mystery decide for himself to which side he shall incline.

The insects named at the head of this chapter are all members of the important order of Hymenoptera, four-winged insects, which include saw-flies, wood-borers, galls and parasitic wasps, ichneumons, spider-killing wasps, solitary and social wasps and solitary and social bees. Between 30,000 and 40,000 species are already known, and it is conjectured that four or five times as many remain to be named. It will be noted that, while a main characteristic of the order is the possession of four wings, the majority of ants have no wings. This, however, is the outcome of specialization which has given the ant world a unique place in the animal kingdom. There are three different forms of ants — the queen-ants and the male ants, both of which possess wings; and the neuter, wingless workers, which enormously preponderate.

An ant colony may be formed either by a solitary queen or by several queens. Within her native home the young queen, in company with other queens, winged males and workers, has shared the common lot and labors of the establishment. She has stored immense reserves of energy within her little frame, and upon the appointed day soars in the air, which becomes blackened with the queens and males of other colonies. It is her first flight, and her last. She returns to earth to begin her nursery duties. The males set out upon

the same day as the queens, and their career ends within a few hours of the flight from the nest. They die that day; they may be destroyed by larger enemies, or they may sink to earth, to die by the wayside. They never return to the nest. Their part in life is played, and with them, as with the drones of the beehive, the curtain is rung down the day that it rises upon their career. The future lies with the queen and the workers.

Chance, so far as we can see, dictates to some extent the future of the queen. She may seek an establishment in which other fertilized queens are already in residence; she may be carried by workers to such a

THE WOOD-ANT, HIGHLY MAGNIFIED

home; or she may select a suitable isolated spot, and there create her own little dwelling. Should the latter be the course, she must patiently await the maturing of her eggs, the slow development of her firstlings, which in this case appear as small though otherwise normal workers, who will take over from her the duty of tending succeeding eggs and young. In circumstances such as these the queen-ant is said not to leave the nest which she makes, but to subsist upon the reserves of tissue built up by her abundant feeding during her time in the nest from which she emerged. She must feed the larvæ with salivary secretions, and, out of her own substance, keep the little family going until the first brood are ready to forage for her. The workers now rapidly extend the city. They make tunnels and chambers in all directions, upon a methodical plan. The proceedings are practically identical with those in which workers are from the first installed. In either event the queen, who has left the parental nest winged and light as air, begins her serious work in life wingless.

Upon her descent to earth, if she be alone, she either bites or breaks off her wings. In the case of one which descends in the midst of workers, the latter may relieve her of all temptation to further flight by themselves biting off her wings. With these workers about her, the now terrestrial insect is in good case. She may eat her fill of the food which the workers bring in. They take the eggs as she lays them, place them in nurseries, carry them from day to day from one gallery to another, even bringing them out of the nest into the sunshine, then restoring them to an underground gallery at night, so that throughout their period of incubation the eggs shall receive due measure of heat and moisture. The eggs hatch, according to the nature of the season, in from fourteen to thirty or even forty days. Small, white fleshy grubs emerge, legless, conical in outline. They are quite helpless, of course, and have to be fed by the workers with food which the latter present in a semi-digested form. Here again the nature, and even the period, of the season determines the rate of growth. While under favorable conditions the larvæ may reach the chrysalis form in the course of a month or six weeks, some species live through the winter in this stage, requiring the unremitting attention of their nurses throughout that period.

The chrysalis may be either naked or it may be invested in a neat silken cocoon. The ants' eggs of commerce, by the way, are merely the cocoon-clad pupæ of ants, not the eggs, which are tiny, yellowish-white objects. Needless to say, the pupa or chrysalis takes no food. The feeding is done in the larval stage; and the seemingly miraculous transformation effected within the pupa-case is wrought as the result of nourishment already assimilated. A shapeless grub begins the transformation; a per-

fect insect, fully grown, emerges. It is interesting to note that the new-comer cannot divest itself of its pupal cloak without assistance. It must be helped to freedom by the workers, who relieve it of its covering, straighten out its limp little limbs, wash and smooth and brush it with all imaginable tenderness, and, when it is able to trot about unassisted, apparently teach it its duties in the nest and beyond, setting it to tidy and garnish, to fare forth and hunt, marking out the dangers which it should avoid, etc. — a whole string of romantic "impossibilities" having been proved realities by observers of scrupulous precision.

A SECTION THROUGH A NEST OF BLACK ANTS, SHOWING PARALLEL PASSAGES

The fact that this instruction is given seems to indicate that the work of these insects springs from instinct and from intelligence too. Instinctive actions are performed without previous training, as the result of a given stimulus. If the actions of ants were simply instinctive, the young ones would not need direction from the adults. It is arguable that the mere imparting of instruction by the adult workers is in itself an instinctive impulse. But where there is apparently selection for duty in the highly complicated economy of the nest, we may perhaps assume that more than instinct is at work behind the selective process. The whole daily round of the life of the ant seems against the assertion that instinct alone guides, impels and controls.

The marvels of that life, and the inference to be deduced from it, are put in a nutshell by Sir John Lubbock: "When we see an ant-hill, tenanted by thousands of industrious inhabitants, excavating chambers, forming tunnels, making roads, guarding their home, gathering food, feeding the young, tending their domestic animals, each one fulfilling its duties without con-

fusion, it is difficult altogether to deny them the gift of reason; and the preceding observations tend to confirm the opinion that their mental powers differ from those of men not so much in kind as in degree."

SLAVE-MAKING ANTS KILLING THE SMALLER BLACK ANTS AND CARRYING OFF THEIR PUPÆ

Upon what is such a claim to be based, if we would prove that an ant is capable of acting intelligently in new circumstances, in which there can be hardly any question of the play of unassisted instinct? Lubbock submitted his ants to many experiments, and that upon which he most relied he himself has described: "My principal experiment was one in which I placed intoxicated ants (he anæsthetized them with chloroform) near a nest, thirty-eight being friends and forty strangers to the colony. Of the friends, twenty-seven were taken into the nest and carefully tended; seven were dropped into the moat surrounding it, and four were left alone. Of the strangers, thirty were dropped into the water, one was left alone, and nine were taken into the nest. Of the latter, seven were again removed from the nest and carried to the water. Could anything more clearly show the reasoning power of ants?"

BLACK ANTS MOURNING A DEAD QUEEN

By what means ant recognizes ant we do not know. It cannot be the power of smell alone, though that sense, which resides in the inestimably sensitive antennæ, is undoubtedly of great assistance for this purpose, as for the detection of food and for finding the way back to the nest. But it cannot be olfactory evidence alone, for ants resulting from eggs taken from one nest and hatched in another are rapturously welcomed upon being introduced as adult insects into their native home; while their foster mothers, if put in with them, are at once destroyed. Possibly we shall never solve all the problems by which the life of these wonderful insects is complicated. We do not yet know all the senses by which they are actuated. It has never been proved that ants or bees *hear*. The voice of the ant no one pretends to have detected, but we all think that we know something of the language of the hive, and fancy that the sounds which we hear there are heard also by the bees. But, as Auguste M. Forel points out, no one has ever detected the auditory organism of a bee, removed it, and proved the insect afterwards deaf. That ants and bees do communicate one with another is as certain as that they live, but it may be the result of tactile impressions; wireless telegraphy may have been in existence in ant-hill and beehive ever since ants and bees reached their present stage of development. If, then, we cannot be certain upon this and similar points, it would seem impossible for us to speak dogmatically with regard to other aspects of lowly life. The progress of science soon makes any finality of statement absurd.

A LONELY MEMBER OF THE INSECT WORLD

THE EUROPEAN MUTILLA, POPULARLY KNOWN AS THE SOLITARY ANT, HIGHLY MAGNIFIED

Something higher than instinct seems to be demanded for an insect which keeps and milks cows! This feature of ant life is one of the most clearly established in natural history. It is practised by more than one species of ants. The aphis, or plant louse, which deposits honey-dew upon the foliage or stems of vegetation, is the cow of the ant. In some cases the ants construct tunnels along the trunk of the tree or shrub which harbors the aphides, and in these tunnels form stables from which the "cows" cannot escape. In others, the honey-yielders are carried down into the ants' nest, and carefully maintained there. But the crowning wonder is that the ants purloin the eggs of aphides, carry them down into their nests, store and tend them during the winter as they store and tend their own, and, when the larvæ hatch, feed them as they feed ant larvæ, and eventually carry them into the open, and place them upon the very plant which constitutes the food of the aphis. And the reward for all this is that the ant obtains the honeyed secretion of the aphis, which it "milks" by gently stroking it with its antennæ, quite after the manner of man.

THE CHAMBERS AND PASSAGES OF AN EXPOSED BLACK ANTS' NEST

A SECTION THROUGH A PORTION OF A WOOD-ANTS' NEST, SHOWING COCOONS AND LARVÆ

The ant colony may contain various other forms of insect life, which are represented as the pets and playthings of the owners of the city. That is as may be; it is not at all unlikely that the so-called pets are harmless parasites, flourishing upon the food supply of their hosts, who tolerate them because of their harmlessness. That they *are* tolerated is plain, for in an instant a colony of ants, with their deadly jaws and lethal equipment of formic acid, could rid their home of every intruder within it. The idea of plaything is, of course, not wholly to be disregarded, for in nothing do ants more closely resemble man than in their apparent love of play. They leap and wrestle and gambol, with the ardor and sportiveness of children or kittens. They seem to show grief and solicitude for the injured and ailing, and, in the case of their queen, apparently mourn beside her dead body for weeks; whereas the dead body of a worker is at once removed, and buried at a distance from the nest.

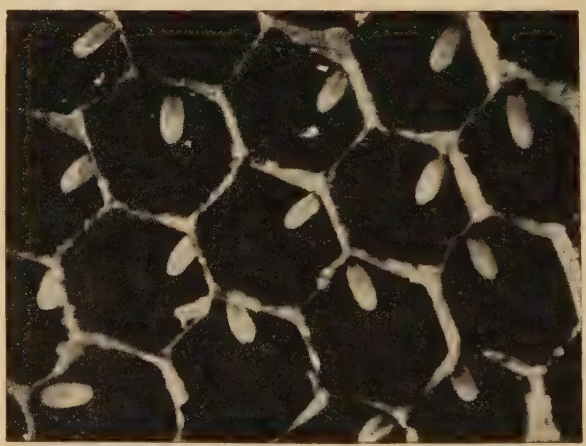
Of course, ants are not an undisguised blessing. The red ant, of the woods, is a menace to anyone who approaches its nest; the ordinary brown and yellow

ants work havoc with our food. The so-called "white ants", or termites, which have a marvelous organization and homes, are appallingly destructive to property. To realize the effect of their attacks upon woodwork, one has but to inspect the exhibits on this subject in any natural history museum. The voracity of ants is almost incredible, their powers of discovering food extraordinary. One observer stored for a night half a dozen caterpillars, with their food, in an old-fashioned wooden matchbox, and placed them in a closet twenty-five feet from the front door, beneath the step of which ants abounded. In the morning the box contained $1\frac{1}{4}$ caterpillars and a swarm of ants, which latter, the moment the box was opened, added insult to injury by carrying off in concert the last survivor and the fragment. Never until that night, so far as could be ascertained, had ants made their appearance in that part of the house.

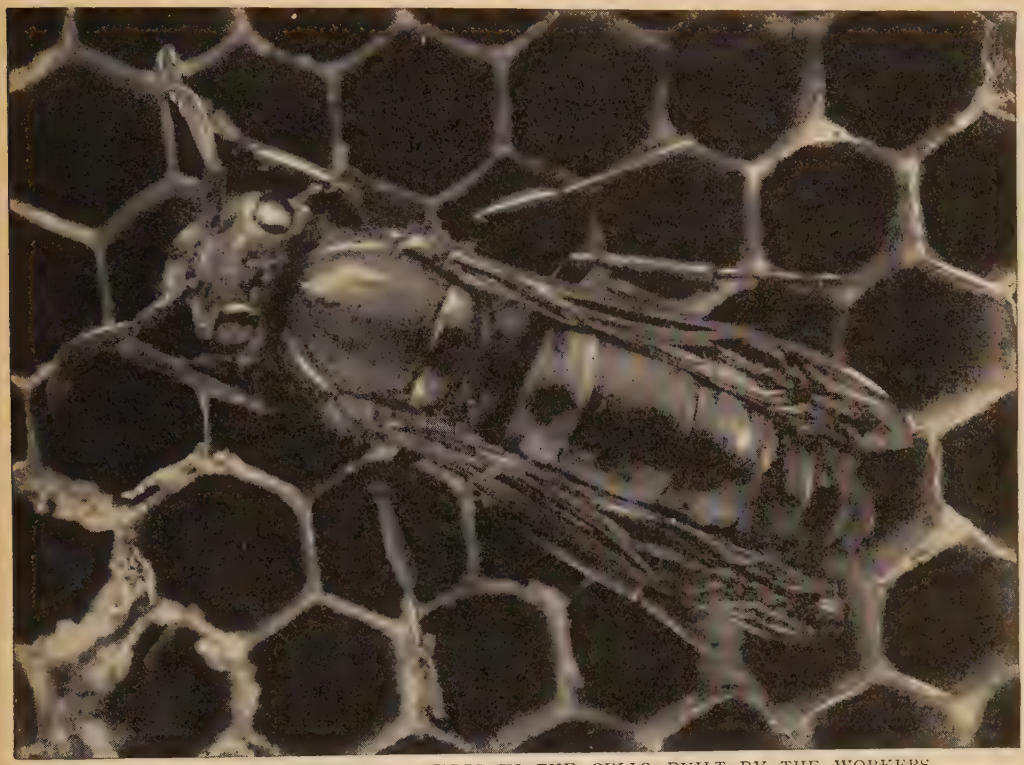
A QUEEN WASP HIBERNATING

A very late frost left one solitary plum as the harvest of an entire wall of fruit in a certain garden, and that plum grew in beauty and promise until the time of picking. The decision to harvest was left a day too late. From a tiny puncture in the plum, when the latter was plucked, emerged ant after ant; it was full of them, though the only external evidence was so small as to be imperceptible until the fruit was taken in the hand. In the spring, when strawberries are being grown under glass, the hotbeds swarm with ants, but when the fruit ripens in the grounds surrounding, not an ant is to be found under glass, though the fruit-trees outside will be found alive with them.

Ants may be troublesome enough in our own land, but there are worse abroad, where they are alternately bane and blessing. One such is the saüba, or parasol ant, which derives its second name from its carrying its plunder in an upright position upon its head; and which is a terrible pest to South American cultivators, and especially to growers of coffee and oranges. These ants live in enormous colonies, whose external indications — far-reaching hillocks — convey no suggestion of the vast ramifications of the tunnels and chambers below ground. One observer gives us some notion by citing an experiment of which he was witness when a gardener in the botanic gardens at Para tried to exterminate these enemies of his work. With this object the man made fires over some of the main entrances to the colony, and by means of bellows blew the smoke of sulphur down the galleries. Smoke was seen issuing from many unsuspected outlets, one being seventy yards from the point of entry. Still larger colonies have been traced. Where the saübas are in abundance they make cultivation practically hopeless, killing trees and shrubs by biting off the leaves. These leaves they use as ceilings for their underground dwellings, but some they store in



RECENTLY LAID WASP'S EGGS IN THEIR CELLS



A QUEEN WASP LAYING HER EGGS IN THE CELLS BUILT BY THE WORKERS

YOUNG WASPS EMERGING FROM THEIR CELLS THROUGH THE SILKEN COVERINGS

order that they may be able to eat the fungus which develops upon it. They enter habitations at night and devour food. It is to these ants that the redoubtable "soldier" ants belong — giants armed with terrific jaws. They accompany the ordinary workers when they go forth foraging, and do battle with any form of enemy, ant or other, which may threaten either the supplies or their bearers.

THE GIANT-TAILED WASP

This insect belongs to the wood-borer group of the Hymenoptera, and the tail is an ovipositor, not a sting.

Another pestilent ant is the fire-ant (*Myrmica sævissima*), which becomes absolutely master of the situation in certain parts of tropical South America. It is in such numbers as to be invincible. These ants have their cities under entire villages, and at their most active season drive away the human population. They enter the houses, and dispute every mouthful of food with the rightful occupants, and devour linen for the sake of the starch that it contains. "All eatables have to be suspended in baskets from the rafters, and the cords well soaked with copaüba balsam, which is the only known means of preventing them from climbing. They seem to attack persons out of sheer malice. If we stood for a few moments in the street, even at a distance from their nests, we were sure to be overrun and severely punished, for the moment an ant touched the flesh he secured himself with his jaws, doubled in his tail and stung with all his might. When we were seated on chairs in the evenings, we had stools to support our feet, the legs of which were well anointed with the balsam." So were the cords of the sleeping-hammocks.

A SOLITARY DIGGER-WASP CARRYING OFF ITS CATERPILLAR PREY

Still more formidable are the ecitons of tropical South America, and the driver-ants of tropical Africa. Although not structurally alike, they are similar in habit. They march in irresistible numbers, and devour every animate thing in their track. They enter houses and clear up every scrap of living matter, from beetles and birds to spiders and scorpions. Nothing can withstand their enormous numbers, their powerful jaws and poison-charged stings; yet it is related that when not on the war-path they may be seen stretched at full length, extending their legs to be brushed and washed between the jaws and tongue of comrades, who finish the toilet operations by giving the antennæ a friendly wipe.

Then there are the slave-making ants, which raid neighboring colonies, kill the adults and carry off the pupæ to rear them alive in their own nests, where the slaves in time become masters, doing all the foraging and fighting, feeding and cleaning their lords, who in time are dependent wholly upon their minions for all the necessities of life.

One other curious ant we must note — the honey-pot ant (*Myrmecocystus mexi-*

canus), which is simply an animated storage depot for honey. The abdomen becomes enormously distended with its contents, and the hapless insects hang head downwards in the cells of the colony, ready to receive and conserve the honey brought in by workers, and finally to redistribute the store when the calls of hunger necessitate a demand upon the treasure. A curious fact noted in connection with these ants is that when a honey-pot dies, the workers do not eat the honey which it contains — the body is nipped in two, and carried out of the nest and buried.

That ants store grain, or rather seed, is a well-established fact. They exhibit great skill in preventing it from germinating, by shifting it from place to place to prevent its being stimulated by heat or moisture, and, in case of failure in this direction, by nipping off the radicle of the sprouting seed. But success is not gained in 100 per cent of cases of this sort. Excessive moisture may prove too much for the efforts of the husbandmen, and they are in that case compelled to carry out their useless grain. Thrown away some little distance from the nest, the germinating seed takes root, and this led to the belief, long accepted, that the ant actually sows and cultivates its crop. Of course, this is a wrong inference, based upon insufficient observation. There seems no doubt, however, that a fungus-eating ant (*Atta sexdens*) deliberately plants her crop, taking her fungus mycelium, tearing up a portion, saturating it with a drop of fecal fluid and carefully replanting it. The process is clear enough. Whether the motive has been correctly estimated is, of course, not so easy to determine.

THE NEST OF THE TREE-WASP

The beginning of a community of social wasps is not greatly different from that of the home founded by the solitary queen-ant. There comes a time in every autumn when only comparatively few wasps are alive in the land. The queens alone survive the winter. The queen goes forth late in the summer for her nuptial flight, and meets the male. Following this event, the queen seeks seclusion and shelter for the winter. The choice of shelter is not invariably suggestive of high intelligence. There is an attic in the home of one entomologist to which queen-wasps resort in winter. How they get in is a mystery; there is no window, and the only visible access is by way of a trapdoor which is not open to wasps. There must be some opening in the roof known to wasps alone. Year after year queen-wasps repair to that cold and cheerless attic. The singular thing is that at the lowest point of the sloping ceiling there is an opening into another attic room where a tank containing 150 gallons of hot water preserves a pleasant temperature, yet never a wasp has been observed there. Only in this one mysterious chamber are they to be found, cold and inert. Needless to say, the queens of that apartment are not permitted to add to the wasp population; of some threescore discovered there last winter, not one escaped.

Wiser wasps find safer shelter; and when the tide of life rises in the spring the queen

seeks a place for a nest — it may be under a roof, or in a bank, or some sunny grass-plot by the wayside. There she rapidly constructs a series of cells of paper-like structure, formed from woody fibers and other vegetable matter. She deposits in each cell an egg. When the larvæ hatch, the queen feeds them with the nectar of flowers and the juices of fruits until the time arrives for the larvæ to assume the pupa form, when they close their cells, undergo their metamorphosis, and emerge neuter worker-wasps. The workers assist the founder of the colony in making more cells, and in feeding the larvæ. Tier after tier of cells is made, and an egg hatched from each. Towards the end of the summer young queens, and after that the males, appear. The earlier generations have all been neuters or undeveloped females. Some of these, however, are capable of laying eggs, which, apparently unfertilized, may develop into males. The young queens and the young males finally leave the nest, never to return. The workers which remain destroy the larvæ left in the nest; then themselves await death. So much for the life-cycle of the social wasp, which, although it eats great numbers of insects, is so destructive of fruit and so venomous an enemy of human beings as to be almost a nuisance. The "hornet" is our largest wasp, and its sting is the most formidable in a formidable array of stings possessed by this undesirable family of insects.

THE NEST OF A HUMBLE-BEE, OPENED TO SHOW COCOONS

Wonderful ingenuity is shown in the construction of nests by various wasps, and it is a fact that these insects were the world's first papermakers. But not all form nests of this material; some of the solitary wasps make their habitations of sand, clay or mud — quite efficient dwellings, though less admirable æsthetically than the beautiful structure fashioned by the wood-wasp, *Vespa*. In the group to which this wasp belongs we find a singular method of furnishing a larder for the young. There being no workers, the parent has to provide food to which the larvæ upon hatching can help themselves. This purpose is effected by the capture of various caterpillars, spiders and other insects. With terrible ingenuity the mother wasp leaves these alive, but paralyzed, in the nest. She stings them in a vital part, and the wretched victims remain motionless, but living, to await the attack of the larvæ's powerful jaws. It seems a hideous transaction, but it is believed that the living prey suffer no pain.

Other remarkable members of the hymenopterous order include wasp-like forms of similar habits, such as the tailed wasps, which, with powerful ovipositor drill, bore nurseries for their eggs in the trunks of trees; the egg-wasps, which are parasitic upon the eggs of insects and spiders; the gall-wasps and the ichneumon wasps; the sphex, which preys in the main upon members of the grasshopper tribe; and the pompilus, which does not hesitate to attack even such large spiders as the mygale, or bird-eating spider.

Finally, in the bees we have representatives of the order in which many naturalists find chief delight. Here, as in the ants, are three forms — the queens, the males and the workers or neuters. But the bees, unlike the ants, will have only one queen in a community. They seem to have solved the sex problem. The queen-mother knows what will result from the eggs that she deposits. She chooses a larger cell than the ordinary ones for the

egg from which a queen is to be produced, and the workers reserve a special regal diet for such larva. But should circumstances arise necessitating the conversion of an ordinary worker-grub into a queen, the change can be effected within a given time of the production of the egg. They need but to alter the diet of the grub from plain fare to royal, and, lo! the intended Cinderella is born a princess!

We may briefly trace the life story of a bee community from the point at which a fertilized queen leads forth a swarm from the hive to found a new settlement. Before taking their departure the bees gorge themselves with honey, in order that they may be sustained upon the way, and that their new home may not lack a larder. In a modern hive they would find foundation-cells already prepared for their reception, and would consequently have less labor. The process is more astonishing in one of the old hives, into which they are dropped or encouraged to enter. Where the queen goes they will go — to death if need be. She is the center, as she is the cause, of every swarm that we see, and she and they can be safely handled when gorged with honey, as they are for such a flight.

Within the hive is a great, black void, vast, in comparison with the size of the bee, as the most titanic cavern to a man. Here a home has to be built. Their only tools and materials are contained within their own organisms. They suspend themselves, one clinging to another, in the form of a curtain, from the roof of the hive, nearly to its base. Hour after hour they hang thus while secreting wax for the cells. This wax makes its appearance from glands beneath the edges of the segments of the body, and is rubbed off with the legs. In the meantime the entire hive has been cleansed by the remainder of the bees. The foundation-stone of the cells is laid at the apex of the hive. Wax, kneaded and rendered plastic, is brought up by bee after bee, is received, molded and fixed by a succession of architects, and a series of walls, each composed of six-sided cells, slowly grows downwards. As soon as a number of cells are ready, the queen, attended by a retinue of maids-of-honor, goes from cell to cell, depositing an egg in each. There is a frantic competition at the outset between the queen and the workers, for she is anxious to lay eggs at a greater rate than they can build receptacles while at the same time providing cells also for the storage of food. But the work goes on day and night, the queen, caressed and fed by her maids, proceeding from cell to

THE QUEEN BEE BEING FED BY THE WORKERS

cell and laying the foundations of the new community. Unerringly she places each egg in the appropriate cell, the drones' cells being larger than those of the workers.

Before she has nearly completed her task the eggs first laid begin to hatch. The egg is a bluish-white little speck, attached for the first three or four days to the bottom of the cell. At the end of that time the minute grub emerges, to float in food supplied in readiness by the workers. When its head reaches the top of the cell, the nurses feed it — a treatment in response to which the larva waxes strong and

A DIVIDED SWARM OF BEES

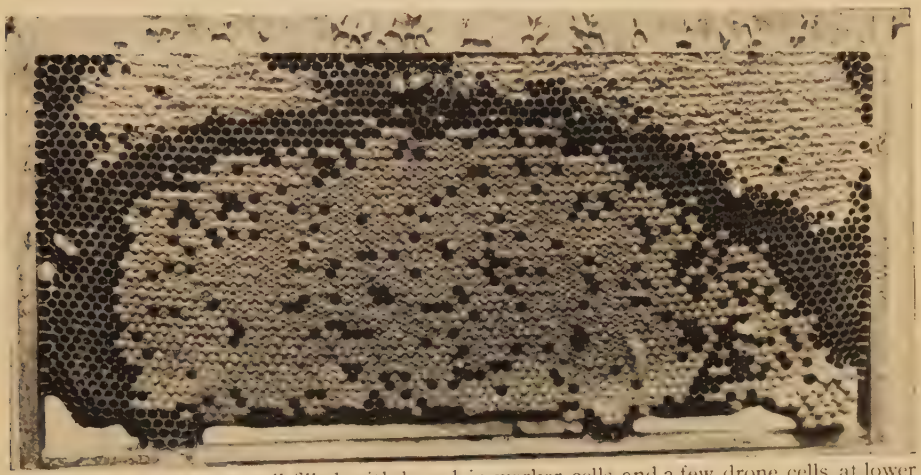
fat. Food is coming in all day long from the workers, which, flitting from flower to flower, collect nectar and pollen. The honey and the pollen, or bee-bread, are separately stored, and there is a grading of the pollen. The grubs which receive the most nutritious food become queens — so few are favored.

It is still a much disputed point as to whether males result from the less nutritious food, but it is fully established that males predominate in the broods of hives poorly furnished with food, or where the queen is old and weak.

The grub, by whatever diet sustained, retires into its cell at the appointed time, and its cradle is sealed with wax by the workers. Within the cell the larva spins itself a robe of silk, and during the next nine or ten days effects the great change from pupa to adult. It gnaws its way out of its prison-cradle, and, after gaining strength, joins the workers in their task of scavenging or engineering, in the cooling and ventilating of the hive, a design effected by relays of bees vigorously fanning with their wings, and so maintaining a continual current of air. But if the young hopeful should prove to be a royal princess, the case is altered — she may not appear with such little ceremony. Princesses may not emerge while the old queen is in possession, or she will slay them. We have by this time, perhaps, got ten thousand eggs in the cells, and, it may be, twice as many larvæ, and a proportion of workers, and there will be seven or eight princesses. The colony is therefore well established; so the queen must lead forth an army to begin afresh; she has thousands of additional eggs to lay. She goes before the princesses make their appearance. As soon as she hears their murmur within the cell she is filled with fury, for queen cannot tolerate queen, nor even princess. She will, if permitted, approach the cell, and, with a thrust of her sting, kill the young life within it. But here the workers, ordinarily so complaisant, interfere to prevent her; they are wiser than their mother and ruler. Foiled, she leads forth another swarm, and later a princess emerges from a royal cell, to be attended by the remnant of workers remaining. She takes her nuptial flight and returns to the hive, where, in due course, she will head a swarm to found a colony of her own.

Should two queens meet in a hive, a fight to the death results, but a wonderful provision of instinct, if such it be, prevents their simultaneously taking advantage of the opportunity to strike a blow when to do so would mean the death of both and a queenless hive. From such a posture both withdraw, to renew the fight upon such terms as shall insure the sur-

WORKER, QUEEN AND DRONE



Frame showing center well filled with brood in worker cells and a few drone cells at lower edge. Upper corners have sealed honey.

Photos Bureau of Entomology, U. S. Department of Agriculture

FRAME OF BROOD COVERED WITH BEES

vival of one. Towards the end of the summer, when it is undesirable that more swarms shall leave, the newest queen goes round to such cells as contain princesses, quietly puts each occupant to death, then settles down to her domestic duties in peace.

The importance of bees to mankind can hardly be overestimated. Their value to the country is infinitely greater than can be reflected in returns from the sale of honey. Bees mean abundance of fruit in orchards which would be otherwise sterile or practically worthless. Fruit-growers are advised by the Department of Agriculture to keep bees on their farms. The reason is obvious. From an ordinary stock of bees there are from 10,000 to 15,000 flying from blossom to blossom from early morning till evening. The result of cross-fertilization by bees is to produce greatly enhanced yields of fruit, and better and larger fruit at that. A fruit-grower in California had under cultivation forty acres of peach-trees. Being dissatisfied with the yield, he decided to cut down the trees and plant others, which he hoped would be better bearers. By the advice of an entomologist, who had noticed that there were no bees upon the fruit blossoms, he purchased two colonies of bees. The beneficial results were evident the same year, for there was at once a fair yield of fruit. So satisfied was he with the experiment that the owner enlarged his stock of bees in the following year, with the result that his trees were laden with excellent fruit.

The breeding of improved stocks of bees is now a well-organized industry, and Japan has profited by the calling, having introduced a number of fertile queens of approved lineage to take the place of her improvident own. The native Japanese bee is a sluggard, taking no thought for the morrow, but living pretty much on the terms of the wasp. The result was that not a tithe of Japanese fruit-trees were cross-fertilized, and not a tithe bore good pears or apples. Queen-bees have been taken to Japan within recent years, and the results are said to be excellent.

Photo Bureau of Entomology, U. S. Department of Agriculture

FINDING THE QUEEN

A SURVEY OF HYPNOTISM

The Different Levels of the Hypnotic State, and How They May Be Used and Abused

STRANGE EFFECTS OF SUSCEPTIBILITY

WHAT we have already learned of the subconscious mind will prepare us to study the facts of hypnotism with somewhat less indifference than the medical profession, as a whole, in this country has hitherto permitted itself. Here is a dominion of fact, not only instructive but of high practical value, which has until lately either been neglected altogether or else employed in objectionable ways. The medical schools have ignored it, notwithstanding the quality and authority of the Old World literature on the subject, which we owe to such men as Charcot and Liébault and Forel. In this country hypnotism, or, rather, the pretense of hypnotism, has been used largely to entertain the public in theaters or side-shows.

The first statement to make about hypnotism is that it is much too serious and important a matter for public exhibition, that public pretense of it is obviously objectionable and that actual hypnotic exhibitions in public would be worse, as being extremely likely to involve serious injury, sooner or later, to the mind and physique of the hypnotized person.

The only person who can benefit by such exhibitions is the real or pretended hypnotist. If he had exceptional powers, peculiar to himself and capable of performing great services for others, there would be a very urgent argument in favor of letting him exhibit them, however distasteful his success might be to more regular practitioners. But the first scientific proposition which we shall here make about the hypnotic process is that the hypnotist does not play the part which the public and his subjects suppose, and which, no doubt, many hypnotists in the past themselves supposed. The accepted idea is that the hypnotist hypnotizes his subject by means of some force resident in himself, and presumably allotted to him in rare and mystic measure. We cannot better understand this question than by briefly looking at the history of it.

We may begin with Friedrich Anton Mesmer (1733–1815), from whose name the word "mesmerism", an old synonym for hypnotism, was derived. He asserted, and very probably believed, that his results were due to a mesmeric force which emanated from himself; and it needs little imagination to suppose that such a force would be electrical or magnetic in nature, or allied to those mysterious and invisible modes of energy, about which we think we know a little. There is, however, not only no evidence that any "mesmeric" force of the kind exists, but also abundant evidence that no such force is needed for the production of the hypnotic effect.

Suppose, then, that we totally reject all ideas of any kind of *physical* force, or mode of energy, that passes between the hypnotist and his subject. There is an alternative. We may argue that the hypnotist produces his effect by a *psychical* force; and in order to confuse ourselves and our subsequent thinking as completely as possible we may call this psychical force, which the hypnotist employs, by the name of "will-power". It is argued, then, that the hypnotist indeed employs no physical means, visible or invisible, but he has an invincible will, to which all must yield.

He imposes this will upon his subjects in the chair, and the deed is done. The successful hypnotist, on this view, will be, like the poet, born, not made. Only here and there, at rare intervals, will a man arise who has in him the "psychic force" of an indomitable will. Others may try to imitate him, but must fail.

"Will-power," in the sense of a psychic force, as absurd as "mesmeric fluid"

Now, just as we totally deny the existence of the "mesmeric fluid" about which our grandparents used to talk, so we deny the existence of "will-power" in the sense of some unthinkable psychic force that passes from the hypnotist to his subject. There is no reason to believe in the existence of any such thing. The will of the hypnotist has nothing to do with the matter, though the will of his subject has much. The manifestations of hypnotism are mysterious and wonderful enough, but we have no reason to suppose that the hypnotist has access to the *psyche* of his subject by any other than the ordinary routes of everyday sensation.

The hypnotist himself may have either a strong will or a weak will. No hypnotist hypnotizes his patient, in the sense in which the public, to say nothing of many who should know better, use the word. The old idea, fostered by the less reputable pioneers, who had their own advantage to consider, was that the hypnotist produced his results by means of the irresistible concentration of his indomitable will upon the helpless personality of his patient. The strong man's eyes glared, his hands made mystic passes, the "cold perspiration bespangled his brow", testifying to the tremendous effort of the will within, and the subject surrendered.

Modern hypnotists sometimes nowadays do not even use their personal presence at all. There is a kind of revolving clock, said to have been invented by Dr. A. A. Liébault of Nancy, which makes a kind of "soothing", whirring noise, and which the hypnotist may set going in the room where his patient is, and when he returns, a quarter of an hour later, the patient may be in the hypnotic state.

The reader who recalls what we observed when studying suggestion in a previous chapter has the key to the facts. Suggestion, as modern psychology terms it, is at the root of them. There is no "mesmeric fluid", no "psychic emanation" from the hypnotist, there is no "will-power" acting from him upon his subject. The hypnotic state is induced by suggestion.

The part played by the personality of the hypnotist

No doubt you may hypnotize a hen by means of a chalk line on the floor, which suggests to her that there is nowhere else to walk than upon it; and upon that line alone she will walk till further notice. Suggestion similarly hypnotizes most of us to walk upon the chalk lines made by our predecessors and fellows; we have to do as they did, just as one sheep must follow another through a hedge; like the hen or the sheep, we can really imagine no other course. Anything may suggest to the suggestible person; and the beginning and essence of the whole of the phenomena is not any mesmeric fluid, any force of will, but the fact of the human *psyche*, shared with the *psyche* of many lower animals, which we call suggestibility.

No doubt it was true that the personality of the hypnotist counted, and no doubt we, in their day, should have framed no better hypothesis to account for its power than our predecessors did. Their view was reasonable enough, in the absence of evidence to show that, so long as suggestion occurred, the agent through which it occurred might be anything — the personality of the hypnotist, the spirit of the mob, a chalk line upon the floor or anything else. But now we know, beyond dispute, that the personality of the hypnotist only plays the part which we readily understand when we recall what we have seen as to "prestige suggestion".

The power of a man to hypnotize himself at any time

When a willing subject is hypnotized, the subject himself is the active agent. He suggests to himself the idea that, in the particular circumstances, it will be possible

to go to "sleep", and he does so accordingly. There is quite enough left for posterity to explain, but at least we have made some progress; the phenomena of hypnotism are not assumed and fraudulent, but do occur; and they do not occur by the action of any psychical agency on the part of the hypnotist. In fact, we observe, the hypnotist may be dispensed with — rather an effective piece of fact against the older theories of the subject.

Many people have learned to hypnotize themselves, and can use their powers to some purpose, especially for inducing sleep. Such cases as that of Napoleon, who is said to have been able to sleep at any time and in any circumstances if he chose, probably involve the equivalent of self-hypnotism or self-suggestion.

The hypnotic state not induced by influence outside the patient

The reader must observe that we have not denied the possibility of psychical influences, perhaps from unknown sources, being able to exert their action upon the hypnotic subject. That may or may not be so. We have only asserted that the hypnotic state is not *induced*, as former generations believed, by any psychical influence from outside the patient. Even where the potent aspect and reputation of the hypnotist, and also his technique, seem most strongly to argue the action of some psychical force upon the patient, the true explanation is that the patient has practised self-suggestion, and that the suggestion — of passing into the hypnotic state — has been made effective, and has, so to say, convinced the self, by using the hypnotist as an argument. If the subject does not believe in the hypnotist, then his aspect and his technique are no argument, and the self-suggestion will not occur.

The absurd devices of the mesmerist quack who plays with hypnotism

Thus we need spend little time upon the manner of inducing the hypnotic state. A Mesmer or a "side-show" quack may practise all manner of "passes", mystic formulæ, accompaniments of darkness or flashing lights, or weird sounds or what not. We realize now that these are not at all essential, though they may serve for the patient or subject whom they suit. A modern, responsible and honorable physician, who practises hypnotism, will employ no such devices. The subject sits opposite him, in a comfortable chair, not facing the light, and is simply asked to collaborate with the hypnotist, and to try to accept the suggestions which he will make. The initial suggestion is simply that the patient shall go to "sleep". We use quotation marks, because there are, of course, certain very essential differences, about to be discussed, between the hypnotic state and natural sleep. The operator assures the subject that in a few minutes he will find himself becoming sleepy, that he will feel the eyelids dropping, the limbs relaxing and that he will then go to sleep. The subject is asked to believe these assertions, and to try to realize them. The hypnotist may gently stroke the forehead, or the closing eyelids, and meanwhile whispers "Go to sleep", "Now you're feeling sleepy", etc. This description of the technique, to dignify anything so simple by the name, may be varied in different cases, but essentially there is nothing more in it than this. The success or failure of the experiment depends essentially on the subject. In so far as it depends upon the operator, it does so in the fashion simply indicated by the fact that, if someone else were to represent himself to be the reputed operator, he would have similar success.

The varying susceptibility of different people under the hypnotist

In the hypnotic state, as under the action of nitrous oxide, there is always the possibility of delusions on the part of the subject. It is an absolute rule, which should never be broken in any circumstances, that the practice of hypnotism should never be conducted without the presence of a third person, for the safety both of the operator and the subject.

Very brief experience will suffice to prove to any operator, whatever his prestige, that different people vary very widely in their susceptibility to his technique, or in their suggestibility. He will have no suc-

cess with patients who do not want to come, who have been bullied or cajoled into visiting him, and either have no belief in his powers, or fear him, or are determined that they will not be hypnotized. Knowing what the process essentially consists in, we need not be surprised at that. He will, in general, be more successful with women than with men, and with the young than with the old. Hysterical persons are, as a rule, readily and deeply hypnotized.

Hypnotization invariably exactly proportional to suggestibilty of the patient

Sometimes the patient is refractory to the process, though willing. After many attempts, at last the hypnotic state may be induced. Thereafter there will be little difficulty, or none, in reinducing it. The proposition knows no exception that the process of being hypnotized is exactly proportional, other things being equal, to the suggestibility of the patient. This has a native, natural basis, which is, in degree, common to us all, though it varies widely in different people, races, ages, sexes, as we have hinted. But it also depends in part upon the experience of the individual. Thus the patient who has once been hynotized becomes, as a rule, far more suggestible ever thereafter. It is almost as if the subconscious reason, if there were such a thing, argued that what has once happened may happen again.

What is the real psychical condition of the hypnotic subject?

What, then, exactly is the hypnotic state? Our answer may content itself with merely noting what may be observed when we look at the hypnotic subject; or we may attempt to define, in psychological terms, the psychical state of the hypnotic subject. The first kind of answer is perhaps a millionfold the easier. Students of the subject vary somewhat in their definition of the various levels of the hypnotic state, and some will describe five or six, perhaps, when others only recognize three or four. The French are the great authorities on this subject, and have given apt and expressive names to the various conditions they have recognized.

Four states of hypnotism which may pass into one another

Here we may content ourselves with describing, first, the state of slight sleepiness, with slightly increased suggestibility; second, the state of definite hypnosis, in which the subject will readily receive suggestions of almost any kind; third, the state of deep hypnosis, in which sensibility to pain is as entirely abolished as in drug anæsthesia, and in which surgical operations can therefore be performed; and fourth, the deepest state of all, which is the same as that of the somnambulist, or sleepwalker.

This classification is not to be too rigidly accepted. There are no abrupt breaks in nature; all transitional stages occur between a liquid and a gas, though we usually fail to notice them, and between the ordinary waking and the ordinary sleeping state. There are many levels within ordinary sleep, and many degrees of awakeness. Such a division of the hypnotic state into levels, with categorical definitions, may be misleading unless we note that the levels may and do pass rapidly or slowly into one another, and that, for instance, your subject, who was at one moment scarcely sleepy, may at the next be in the deepest state of automatic behavior, after the fashion of somnambulism. Further, while one subject will pass rapidly into the deepest state, another may never, by any device, be advanced further than number two, or even beyond number one. Nevertheless, such a classification as we have given is fairly representative of the facts, and has very evident uses. We know, with some accuracy, what are the possibilities, the advantages and the dangers of any of these states, and we may deal with them accordingly.

The deep state of hypnotism which may seriously impair the patient's mind

The fourth, or deepest state, may briefly be dealt with first, for the sufficient reason that it is to be altogether avoided. It has no uses or advantages for any of the therapeutic purposes which we shall shortly consider. Indeed, it has definitely unthera-

peutic properties of its own. The frequent induction of this psychical condition may prove to be very injurious to the patient's mind. No responsible hypnotist would ever deliberately induce this state in any patient, or any subject upon whom he was experimenting; and if this state were to occur, the hypnotist would at once rouse his patient, and take care not to let it occur again. The hypnotist can always rouse his patient by telling him to awaken; if there is ever an exception to the rule that this process involves no difficulty, and is practically instantaneous, it is in cases where the deepest hypnotic state has occurred. Sometimes, then, there may be some difficulty in arousing the patient.

THE SLEEP-WALKING SCENE IN SHAKESPEARE'S "MACBETH," AS PLAYED BY MRS. SIDDONS AT DRURY LANE — FROM THE PAINTING BY TALBOT HUGHES

The sleep-walking adult or child should be well looked after, and protected from risk. Not only so, but efforts should be made to get the patient out of the habit, which is not a good one. Doubtless, in most instances it may lead, or seem to lead, to no harm, but we know too much about it now to look upon it with equanimity or jocularity. Those who are in this state are not very far removed from an unquestionably morbid and injurious condition of the mind which is known as catalepsy. Here the self, the personal will, the autonomy, of the patient have completely surrendered their powers. The patient has become an automaton.

In the so-called "waxen catalepsy", the limbs may be set in any position, and there they will remain until sheer muscular exhaustion compels them to drop. The patient is like wax under the modeler's fingers. One eyelid may be opened and the other closed in the morning, and so they will be found when the subject is visited again in the evening. It may readily be imagined that catalepsy, whether lasting for months or a few hours, can scarcely be desirable for the health of the mind. Cataleptic seizures too often hasten the mental degradation witnessed in lunatic asylums. We do not here assert that occasional sleep-walking is to be regarded with unreasonable alarm — it is too commonly devoid of

serious results for that — but we do assert that the condition is not normal, but morbid, though perhaps only slightly so; that it should be dealt with by suitable rules during the day, and that no responsible hypnotist can ever willingly induce this extreme state of hypnotism in his patients, or the subjects of his experiments.

The hypnotism of the sleep-walker and the hypnotism of the day-dreamer

Those who may have to deal with a sleep-walker should know that the phenomenon, though remarkable, is not occult or diabolical, or dangerous to anyone but the sleep-walker himself. The absence of fear from the mind in the somnambulic state permits of feats, walking along parapets, etc., which would otherwise be impossible. To "waken" the somnambulist by shouting at such moments is, of course, to court disaster. When he or she is accessible, the simple suggestion to go back to bed will be readily and certainly complied with. Then let the ordinary state of waking consciousness be restored in physical safety there, and without alarm or shock to the subject's mind.

So much for the deepest level of the hypnotic state. For convenience, let us now deal with the slightest degree of hypnotism, which many casual observers would perhaps pass unnoticed. Patients who consult physicians practising hypnotism, for relief from neuralgia or insomnia or nervousness, or what not, may frequently find it impossible ever to pass into a deeper state than this of perhaps very slight drowsiness, with the ears "attuned" and sensitive to just one sound, the voice of the hypnotist, and the mind rather more ready than normally to credit what he says.

Suggestible people no doubt pass into this state more frequently than is sometimes supposed. The ardent lover of nature or of music may sometimes find himself in a state of "day-dreaming", or something like it, which is practically the same as we are here describing. Many a girl has disastrously yielded to her "lover's" suggestions when in this state. It is probably induced very largely in certain parts of the world at religious "revivals".

The efficiency of suggestions of healing in slight cases

The structures of the mind which are very closely concerned with the more emotional forms of religion, and those concerned with the interests of sex, have been known in all ages to be allied. Under this condition of slightly heightened suggestibility and irresponsibility, people follow one another's example, and yield to the entreaties of a "revivalist", but their self-control is weakened in other ways.

In the medical practice of hypnotism, this shallowest level of hypnosis may often be very useful. The hypnotist would much prefer to induce a deeper "sleep", but often he cannot, especially in the more rational type of patient. Nevertheless, if only this light hypnosis can be induced, "suggestions of healing", or "therapeutic suggestions", as they are called, may often be efficient. This will be so especially in slight cases of distress, such as insomnia or neuralgia. Too often, however, the suggestions made when the subject is in this state are not effective, or retain their effect for only a very short period of time.

When a man may be physically asleep and mentally awake

For therapeutic purposes, the second stage, according to the definitions we have employed here, is the valuable one. The patient is now really "hypnotized". The pulse and respiration are probably calm and rather slow, as in sleep. *Hypnos* is Greek for "sleep", and we call a drug which induces sleep a "hypnotic". But hypnosis is not sleep. In many physical particulars the patient may be asleep, but he does not let his head nod, or his jaw drop. Further, parts of his mind which are asleep in true sleep are not asleep now. He can hear and see, as Trilby could hear the notes which she had to sing in Du Maurier's novel. But the patient's reason and will *are* asleep. Hence the patient will accept suggestions, but not all suggestions. The hypnotized hen will only walk along the chalk line that has hypnotized her; no other lines are any good to her. So here the subject will listen to the suggestions of

the person who has hypnotized him or her, but not to the other people's. The spectator may try to "waken" the subject, by any violent means, but will fail. If the operator merely whispers "Now waken", the subject will open the eyes, look round and recover the normal consciousness at once. The spectator may give orders or make suggestions; they will be ignored. The subject has therefore not surrendered all will and all reason. There is what, the powers of language failing us, we have called a subconscious reason, and even a subconscious will, at work.

Subject on waking has no recollection of orders of subconscious mind

Provided, as we saw in an earlier chapter, that suggestions be not made which are contrary to the whole character and moral feeling of the patient — and which will be rejected with signs of disgust or horror — the subject will now do whatever the operator suggests. In other words, the most characteristic and important descriptive fact of the hypnotic state is heightened by specific suggestibility. For we have seen that the subject is no more suggestible than usual to any source of suggestion but one. From that one source alone, however, almost anything will be accepted. The subject will blow the nose, sing a song — usually not at all like Du Maurier's description of Trilby's singing — get up and do any absurd thing. It looks, certainly, as if the will of the operator had established itself in the mind of the patient, and, with important reservations, as we have seen, that is so. To be more accurate, we may say that the will of the operator has established itself in the *subconscious* mind of the patient; and the consequences will be according to the natural properties of that subconscious mind. They now begin to be revealed.

For the operator's suggestions do not merely apply to the patient's behavior while he or she is in the hypnotic state. On the contrary, the operator may say that, in eleven hundred or two minutes from that moment, the subject, whatever he or she may be doing, is to go to the dining-room and put the dishes under the table, or close the blinds, or empty the pitcher out of the window — and it will be done. On "waking", the subject has no recollection of the order; the ordinary waking mind has not heard it, but somewhere, somehow, the necessary calculation will be made; and at the appointed moment the subject will find himself, to his own great surprise, leaving his occupation and performing this absurd act, for no reason which he knows. The subconscious mind is obeying orders, and giving orders accordingly.

We might multiply indefinitely the authentic accounts of what suggestions received in the hypnotic state will cause a subject to do. The scientific fact is simply that this heightened suggestibility occurs, and that its consequences *outlast* the hypnotic state, and show themselves even when the subject has returned to the more moderate suggestibility of his ordinary life. Like the man of mature years who, in a crisis, obeys suggestions made to him when he was at his mother's knee, the subject finds himself obeying orders of which, in this case, "*he*" has no recollection whatever. He could truly swear that he had never heard such a thing, to say nothing of remembering, but the subconscious mind heard and remembers, and orders accordingly.

The value of hypnotism in the treatment of illness

It is evident that here are therapeutic opportunities. Let us try to relieve cases of illness, distress, disordered action of any kind, which may perhaps have their origin in the subconscious mind, as, failing deeper knowledge, we can but call it. We can surmise, for instance from our own experience in strange bedrooms, that the subconscious mind — not the personal will, but a kind of will beneath it, which our will cannot control — plays a part in the induction of sleep.

Again, we are aware that there is some nervous control of the action of the bowel, though this, like sleep, is not under voluntary control. Might it not be that cases of insomnia, or of constipation, could be cured outright without drugs or difficulty

if the patient could be hypnotized and have suitable suggestions made to the subconscious mind when the ordinary reason and will were in abeyance? If the suggestion be made when these are not in abeyance, they will obstruct it. The reason says, from its experience, that this is nonsense — one cannot go to sleep at such and such an hour because someone says so. But if the will and the reason can be, so to speak, "short-circuited" and the suggestions, though irrational, can thus be accepted by the subconscious mind, they may be effective.

In such cases, the results are often wholly admirable. The patient has had the suggestion made that at ten o'clock in the evening he will go to sleep, and will remain asleep, without dreams, for eight hours, and awaken, refreshed and ready for hot milk at six; and he simply does so, though all manner of devices have utterly failed to give him such sleep for months before. Exactly similar means may suffice to cure constipation; the patient is told that the action of the bowel will be as regular as clockwork thereafter, and it is.

The people who can be hypnotized and those who cannot

The principle may be laid down that whatever morbid conditions of the body or of the mind are under the control of the subconscious mind may be controlled by therapeutic suggestions received during the hypnotic state. A certain number of people cannot be hypnotized, and these possibilities are therefore not for them. Others can be hypnotized, perhaps by one operator, but not by another; and others can be hypnotized by anybody — that is to say, they are so readily suggestible that, whenever the conditions favor at all, they will accept the suggestion of passing into the hypnotic state.

For those persons who can be hypnotized to some definite degree, this measure offers, in capable and responsible hands, advantages which no other form of therapeutics can command. Practitioners who are too sanguine and too little critical may be willing to employ hypnotic suggestion in cases where it cannot reasonably be expected to succeed — say, in cases of *lupus vulgaris* (tuberculosis of the skin), a malady which has nothing to do with the subconscious mind. But the right kind of cases have yielded extremely good results.

The European doctor who would hypnotize a patient to give him sleep

In Europe, hypnotism is said to be now often employed for therapeutic purposes. We are told, for instance, that sleep is induced by its means in cases of pneumonia, where sleep is so important, and where the use of drugs in order to obtain it is so undesirable. To the best of the writer's knowledge, hypnotism has never yet been employed for such a purpose in this country. In all forms of insomnia, hypnotism may be extremely useful. It has won similar success in nervous constipation, as we can readily understand, and in all kinds of nervous pains — neuralgia, tics and aches. In the various forms of hysteria, hypnotic suggestion may prove very useful; and the hysterical patient is usually an easy hypnotic subject, though it is said that in such patients the suggestions require to be repeated, losing their force after a time much more readily than in other patients.

The opportunity of the hypnotist to strengthen a patient's will

In the discussion of hysteria, now many years ago, Sir James Paget remarked that, while the patient says "I cannot", and her friends say "She will not", the truth is that she *cannot will*. In the cases of hysterical paralysis which are so familiar to doctors, this dictum is well illustrated. The patient's bones, joints and nerves are all in order, but she cannot walk, or can only whisper, because she *cannot will* the activity of the muscles of her legs or of her larynx. Here is the opportunity for hypnotism. In typical hypnosis, as we have seen, the patient's conscious will and reason are "short-circuited", and the suggestions of the hypnotist have direct access to the subconscious mind of the patient. He tells her that she is to walk — for she can walk perfectly well — and she does so. He tells her, further, that on "waking" she will be able to walk, and so she does. We

may interpret this in various ways, but the most reasonable seems to be that which argues for the reinforcement of the subconscious will of the patient by means of the hypnotic suggestions. When we say the patient "cannot will", we do not mean that she "herself" does not will to walk. She does; she is more willing to walk than we are that she should, poor thing. She does will, but she does not will effectively.

The immense value of hypnotism in curing bad habits

We realize now how many levels the mind has. The highest level here, the level of conscious will, wills as it should. But what we have here ventured to call the subconscious will, the chief servant and executor of the conscious will, is out of order. To say what is the matter with it would be to solve the problem of hysteria. But the suggestions of the hypnotist come to the rescue; and thereafter the conscious will of the patient becomes effective.

There are many other cases in which hypnotism succeeds; and if we remember our theory of its action we shall readily understand why it may succeed in these cases, and must always be entirely futile in others. In many cases of bad habits, therapeutic suggestions received in the hypnotic state may effect a cure when everything else has failed. Perhaps many cases of hysteria are really a kind of bad habit of the subconscious mind, and thus come almost into this category. Bad habits in childhood, such as incurable biting of the nails, and habits much more inconvenient and injurious, may be cured by hypnotic suggestion. In adults, inebriety and all forms of drug addiction may in many instances be cured by hypnotic suggestion; and the serious student of inebriety, who knows of how many and various underlying conditions this may be the mere symptom, will be able to predict the type of case — the weak-willed, well-meaning, neurotic drinker — in which this method may be successful, *because* it reinforces the too slack powers of the subconscious mind. But little can be hoped from hypnotism in the case of the defective-minded or the vicious drinker.

Why hypnotism is more widely understood in Europe than in this country

In Europe the study of therapeutic hypnotism is much more advanced than in this country, because the very characteristics of the medical profession are characteristics of the race from which it and its patients are drawn, and this race does not furnish the best hypnotic subjects.

For them we must go to the more excitable, hysterical, suggestible peoples of France and southern Europe. It is among such peoples that hypnotism will show its most marked phenomena, and therefore among them that it can be most useful in medicine. The deeper levels of the hypnotic state can be more readily induced in the southern European subject; and hence we find, as we might expect, that the records of the medical, or rather surgical, use of the third level (with cutaneous anæsthesia) in place of the use of chloroform or ether, are derived entirely from there.

The surgeons in this country have had but little recourse to the use of hypnotic anæsthesia, and they are probably quite right on the whole. At the same time, every surgeon is familiar with cases where an operation should be performed, but the giving of any anæsthetic is too risky, owing to the state of the patient's heart; and in such cases hypnotic anæsthesia *might* be used.

Cases of the relief of pain, and of the induction of anæsthesia for surgical purposes, by the use of certain kinds of light, especially blue light, are sometimes recorded in the newspapers as having occurred in Europe; and our reader may wonder why, since chloroform and ether are not free from risk and discomfort, anæsthesia cannot be comfortably induced on this side by merely exposing the patient to a "soft blue light". No surgeon lives who would not be glad to use blue light instead of chloroform if he could. But the fact is that the blue light, or whatever it is, merely serves as the suggestive agent, and the patient about whom we read has been hypnotized into anæsthesia. This is very excellent, when the patient is such that he or she *can* be suggested into hypnotic anæsthesia by

the simple magic of a blue or any other colored light. But in this country such patients are not known of, though they may exist in considerable numbers, and the surgeon accordingly cannot count upon the suggestibility of his patient.

The halcyon days of hypnotism that are passing away

But, the more we know about suggestion of any kind, the less suggestible we become, and this fact has to be remembered when we incline, as some have inclined, to the view that the practice of therapeutic suggestion has an unlimited future in front of it. Perhaps its possibilities are only beginning to be realized, but if we analyze the facts upon which they depend we shall see that the printing-press and the school, and the spread of scientific ideas, are their enemy. Thus the halcyon days of hypnotic suggestion would seem to have been those before Gutenberg and Caxton.

The famous French neurologist, Charcot, has left us the most remarkable descriptions of the phenomena he was able to elicit when first he began to study the possibilities of hypnotism in Paris. He would get a whole wardful of ignorant and superstitious peasant women, ready to believe anything, and then could control the behavior of one after another, in any fashion he pleased by a mere word. Where he directed, they would feel agonizing pain, or be relieved of it; there would be only one effective conscious will in the room, and the rest of its occupants would be his marionettes.

We may perhaps be allowed to doubt whether Charcot would have been quite so successful in this country at this time. So much for the chief phenomena and the therapeutic possibilities of the various levels of the hypnotic state, as well as we can define them.

The wise doctor's patient who saves himself by believing

But let the reader beware of supposing, against our frequent warnings in these pages, that there is any absolute line between the ordinary waking state and the heightened suggestibility of the hypnotic state, any more than there is any absolute line between waking and sleeping. Short even of the shallowest level of the hypnotic state, with its slight sleepiness and slightly heightened suggestibility, there is the measure of recipient expectancy which any or all of us may have, in varying measure, at any time. This is what doctors hint at when they talk of a "good bedside manner"; this is why the great consultant from the city cures the patient whom the country doctor knows far more about but has failed to relieve, and cures him by the continuance of the same treatment. The patient believes, his unconscious mind has had suitable suggestions effectively made to it, and he gets well. This is why a sterile salt solution from a hypodermic syringe, being called morphia, has sent many a patient to sleep, and why many attacks of indigestion and lack of appetite, etc. have been relieved by a prescription containing simple ingredients but written in Latin. The same ingredients written in English would not have been as effective.

This also is why the great doctor, the perfect nurse, the friend in need, the leader of men, the persuasive teacher, the reformer, the pioneer, is born, and not made, and why science and skill, without the magic of suggestion, can never avail against that magic alone. The only difference, perhaps, between the wise and the foolish, is that the wise men are wise enough to know, and the others do not know, which are the suggestions, and who are the suggesters worth listening to.

THE GENTLE PATH TO AGE

Cardinal Rules for the Guidance of Men and Women Past Life's Most Perilous Periods

THE MAINTENANCE OF MENTAL YOUTH

IF man is primarily a mind, the physical aspects of growing old cannot comprise all that we have to learn. The happy few, as we occasionally encounter them, have the secret of perpetual youth, and the secret is contained in no flask or vessel, no powder papers or injection syringe. Youth is a state of the soul, and the elixir of youth must itself be spiritual.

Too little is yet known about natural old age, just as too little is yet known about normal death; the cases are so rare. But we may certainly deny that, after the period of adolescence, years are any real criterion of age. It is true for the tree that its very structure measures the yearly revolution of our planet round the sun, but *we* neither lose nor lay a layer of our persons in correspondence with this revolution. So far as the body is concerned, the arteries are the best criterion of age, and their state is certainly not dependent on the passage of time as such. A man is as old as he feels. The woman who decides to have no birthdays is perfectly warranted in so doing as long as her mind remains young; but if her mind remains young, she will not worry about her birthdays in any case. Nothing will arrest senile changes in the skin, but it is possible to arrest, if not to prevent, senile changes in the mind.

To some extent the nature of normal old age in man may be inferred from our observation of the lower animals; but most of the animals we observe are domesticated, both overfed and under-exercised, so that there is a source of fallacy there, too. Most of what we call old age in man is a morbid deterioration, the beginnings of which may be well marked in the thirties, or, on the other hand, may scarcely appear in the eighties. So far as the mind is concerned, the difference between ten and twenty, or even between twenty and thirty, is necessary and unmistakable, but it by no means follows that any substantial difference between thirty and sixty is necessary. We can all observe or quote notable instances to the contrary.

As compared with the child, the adult is less capable of making nervous acquirements. This power of making acquirements, or of learning by experience and practice, is an expression of adaptation. Every living organ, or function, in losing its power of adaptation is on the high-road towards death. All such power gone, there is either absolute death or else death in life. Let us beware, then, of the loss of power to change our minds. The man who can no longer change his mind will never change anything outside it; he will never be a cause again, except as an obstacle is a cause.

The rate of change in the modern world is so enormously accelerated, however, that it is daily becoming easier for us to retain our mental adaptability. We live in an atmosphere of change and development, the importance of the influence of which on the mind cannot be denied. We see it when we compare the average city dweller with the average backwoodsman. The conclusion is that mental movement, alertness, development around us do directly exercise the mind so that it keeps in condition.

The wise man, therefore, who wishes to remain essentially young, will carefully ensure such mental surroundings as involve a mental gymnastic and constant mental refreshment. If he has his choice, this requirement will be complied with alike in work and play. First, then, the elderly require the company of their juniors. The young, children and adolescents, beat us in memory, in curiosity, in agility of mind, in receptiveness and in sheer joy of living. But by the laws of suggestion and imitation they can communicate these advantages of theirs, in some measure, to the minds of their seniors. Natural young people are good company for everybody. They are, of course, good company for each other, and the solitary child is greatly to be pitied, unless its elders are really still young in mind. But above all are young people good company for their seniors. Those elderly people who, apart from special causes like illness, cannot put up with the company of properly behaved young people, are already old in essentials, and betray the fact beyond any doubt or dispute.

The knack of growing young in the company of youth

The way to keep young is to be much in the company of youth. The great principle is, "Be a boy as long as you can". He who can spare some of his hours from the ways that are dark and the tricks that are vain of his adult compeers, to the company of children, will find that their interest in things and their joy of living are infectious, as every emotional state is infectious through the omnipresent mental fact we call suggestion. Thus old people can be observed growing visibly younger when they are put in young company. And here, of course, we have a ready explanation of the fact that, if other things be only approximately equal, fathers and mothers look, feel and are younger at any given age than their unmarried contemporaries. But when we praise the young for their use to the old in this connection, we should remember that this service rendered by the young involves some risk to themselves. They do not benefit reciprocally. Virtue goes out of them, but no corresponding virtue enters, except the negative virtue of discipline. Therefore we must be careful not to shut the young up, without relief, in the company of the elderly or old, unless, indeed, those fortunate seniors be truly young in soul. Not a few instances might be recorded where a tendency towards melancholy, introspection and actual melancholia on the part of the young has been disastrously exaggerated by the lack of healthy young company.

The possibility of indefinite mental progress in defiance of age

Though it may be true that we cannot learn the violin at twenty, and in general that the possibility of making neuro-muscular acquirements becomes severely limited after youth is past, yet, so far as the higher attributes of the mind are concerned, we should progress indefinitely. This capacity for unlimited mental growth is our unique privilege, just because we are not solely instinctive beings, but have that infinite, limitless thing called intelligence. Man is the only creature in which intelligent plasticity is limitless. So far as we are concerned, we *may*, if we be wise enough, learn and change and grow in our eighties or nineties as at any other age.

One of the secrets of youth is to keep working; not necessarily money-making, but working. Everything, except spiritual old age, comes to him who works. Not only is it better to wear out than to rust out, but it takes much longer. Indeed, the mark of the living organism, as we watch it from day to day, is that it does not wear out, because, unlike other machines, it has the power of internal re-creation. We have been evolved from a lower type largely by the struggle for existence, and are therefore strugglers by constitution. When we cease to work, we degenerate. In five years after retiring from business or from work, a man commonly ages more than he did in twenty preceding years, unless he is fortunate enough to have some hobby or interest — children or china, or whatever it be — that saves him.

The necessity for always learning something, that the mind may go forward

And just as one must keep on working, so one must keep on learning. Simply to learn for learning's sake is worth while, at this later time of life, for the sake of the mental gymnastic. The learning of Greek roots, the vagaries of irregular verbs and particles, and the like is a pitiable exercise for the child's mind. A great deal of the subject matter of what we at present call education would have a useful place, however, in filling the otherwise unfilled hours of elderly people. At any rate, if they can find nothing better to learn, it were better to memorize a page of irregular verbs than to learn nothing. From such verbs the learner may proceed to an interest in etymology and philology. Entomology would do as well, or any other "ology" which means that the mind *goes forward*.

Another cardinal rule for the preservation of youth is to preserve the optimism of youth. It may be said that this is just what the old man, because he is old, cannot do; but that is only partly true, because it ignores the native, original powers of the mind in itself. If the old man finds occupation, and recognizes the danger of incipient pessimism, he can protect himself. Here are some entirely admirable observations on the subject from Professor Forel: "The modern man wears himself out in restless earning in order that he shall be able to rest in old age. But when the man who has worked all the time gets old, he discovers that without work he can no longer exist. Only the idler and the pleasure-seeker who has squandered his life becomes even lazier than ever in his old age — if that is possible — because he has never exercised his neurones (nerve cells). If anyone wants as happy an old age as possible, he must first of all never betray his optimism; second, never brood over the past and the dead; third, work away to the last breath, to keep as much of his cerebral elasticity as possible."

Special attention may be directed to the advice not to brood over the past and the dead. This is of cardinal importance for the elderly. They *must* look forward.

The fatal error of living too much in the past

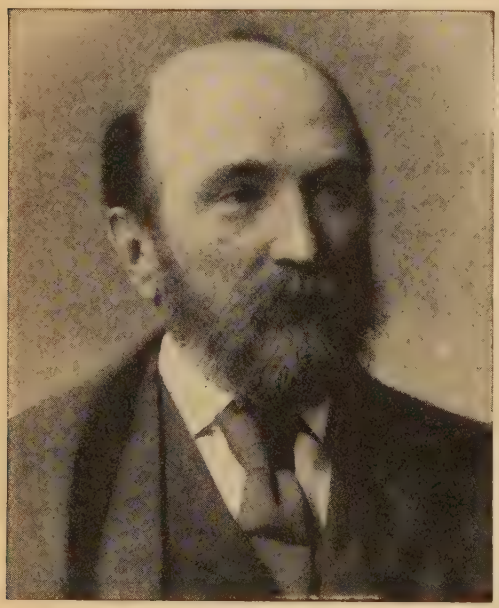
The penalty for the backward gaze is the penalty that was exacted from Lot's wife; you are turned into a pillar of salt, or something equally destitute of life. It is well and right to love and admire the past, to be grateful to it and to learn from it. But never can it be right to live for the past. This is the only too common tendency of nations, institutions and individuals, and the consequent fate of all is the same. The nation or institution or individual that would survive must live for the future. There may or may not be evidence of purpose in nature at large; there must be evidence of purpose in man, or he is doomed. The mark of the old man who is not really old is the forward gaze, whereas to live for "the day that is dead" is to be dead to the day that is alive.

Life is change, and so the mind must be open to change

So little attention do we yet pay to mental hygiene that on every hand cases are to be seen where the body seems verily to have survived the soul. The mind has lost its capacity to change, and so is no longer alive — for "to live is to change", as Newman said. Death of the soul is a tragedy not for one but for all; some of these dead souls are very malodorous, and highly injurious to the public health. Those of us who love and admire ideal old age, wherein experience and judgment and charity and patience have been added to, but have not replaced, the enthusiasm and optimism and modifiability of youth, must in similar measure deplore, if not loathe, that real senility of soul, to be found at all ages, which has lost all ideals, all purpose, all onward vision, and spreads nothing but contagious death. On the other hand, it can hardly be possible to overestimate the advantages which the society of the future will reap from the application of the scientific study of the mind — when old men as well as young shall see visions, and shall lead the world instead of lagging behind it.

In "The Hygiene of the Mind", Sir Thomas Clouston insists upon the value of occupation and purpose in old age, or rather in the postponement of old age.

"The typical environment of old age," he says, "consists of a quiet home, sons, daughters and grandchildren, not necessarily living in the home, but frequently accessible." Cicero knew this, as readers of his famous book "On Old Age" will remember. Again, Sir Thomas Clouston insists upon the importance of the conscious effort to preserve the youth in one: "It is best carried out by seeing young people, by efforts to sympathize with them,



SIR THOMAS CLOUSTON

and even by following at times and in a mild way some youthful pursuit or game." He continues, with these observations.

"A gentle contentment with life comes naturally enough to normal old age. The very opposite state comes to the explosive and pathological variety of it. It is marvellous how happily nowadays many men and women of eighty get through the twenty-four hours. I met such a man lately, who had led a busy, intellectual and practical life, and I asked him, 'Doesn't time hang heavy on your hands?' 'Not at all,' was his reply; 'I never was so busy in my life, the days seem too short for me.' He had, in fact, resumed hobbies and work of the right sort which he had not had time to do in his younger and busier days. Loneliness is certainly bad for the old. The brain and mind need the right sort of stimulus, and if they do not receive it they fall into a moody, selfish isolation. There is one trait which I have seen in some old people which is the cause of much misery — a jealousy of the young. The unreason of this is only equalled by its evil practical results, because it alienates and sends away just those social elements that might be helpful and hygienic."

If principles such as these were generally known and acted upon, what is too often the burden of the older generation upon the younger would be transformed into a boon. Human progress would be accelerated, and the reverence for old age, which, like other ancient and excellent things, is now out of fashion, would be warranted by the existence on all hands of old people, of both sexes, whose claim to "honor, love, obedience, troops of friends", was indisputable. It is one of the notable facts of vital statistics that the fall in the death-rate is mainly due to the keeping alive of elderly people under modern conditions. This is the same as what the alienists call the "accumulation" of the insane, causing an apparent increase in their numbers, merely meaning that they live longer. But it is of little use to live longer if senile dementia is the essential fact of the last period of life. This is only a death-in-life; and the problem for a complete hygiene today is to keep the mind alive as well as the body. And this is precisely where Metchnikoff, in his observations on old age, and the physiologists in general, fail us, for their studies are concerned with the body alone.

But if we are right in regarding the mind as the central reality of man, and in declaring that youth is a state of the soul, we must complement our physiology with an appreciation of the various psychical factors concerned, as we are here attempting to do. The mind depends on the body, we seem clearly to see, but the converse proposition is no less true, though the whole tendency of nineteenth century

medicine was to deny it. The body also depends upon the mind, and the factors of old age are therefore also to be sought among the psychical characteristics of "middle age", as it is commonly called. Doctors are in the habit of referring to "middle age" in their patients, somewhere after the age of forty, as a period when the individual must remember that he is "no longer young". The "middle-aged" man is told that he must begin to take more care of himself, that he cannot expect to have his former powers, and that, if he is wise, he will abandon the notion that he can enjoy life in all its variety as he used to do. The term "middle-aged" is thus definitely used as an *unhygienic* influence upon the mind. The man teaches himself to regard his condition as one of lost youth, begins to look anxiously for signs of actual decadence, and very commonly begins to coddle himself, on the ground that a middle-aged person requires to be careful of himself.

This is the double way, partly mental and partly physical, in which to hasten the advance of old age. Before the practitioner is entitled to give advice of this kind to his patients, he should study the normal facts of a human life-history. He will then learn that, as we have seen elsewhere, the period of "middle age" is really the period of *maturity* in the characteristically human attributes of our species, and should be so named accordingly. The bones, the muscles, the joints — which are the most mechanical parts of the body, and which are not characteristic of man at all — these already show signs of decadence in the period of middle age, and the wise man will therefore not attempt to emulate, in gymnastics or violent forms of athletics, the feats of his juniors. But in higher qualities middle age is really human maturity. The brain is at its best as an organ of thought after forty. The vital powers of resistance and control and self-manage-

"TIME GIVES TO HER MIND WHAT HE STEALS FROM HER YOUTH" — FROM THE PAINTING ENTITLED "THE BLIND ABBESS", BY TALBOT HUGHES

ment are also at their height in many respects. The man in his forties, therefore, who has taken proper care of himself, should regard himself as *mature*, not "middle-aged", and the problems for him are, first, to enjoy and use and appreciate his maturity, and, second, to maintain it as long as possible.

Where men and women alike fail in the right care of maturity

The "cure" of old age can never be more than only the care of it, but the advent of old age can be postponed by the right care of maturity, and it is just in that right care that so many men and women fail. They quickly begin to follow the misleading and worse than worthless advice which is too often offered them. They begin to take care of themselves in ways which really mean over-indulgence, whether in food, drink, warmth and idleness, and quickly they lose their only recently gained maturity of mind and begin to go downhill. Of little use is it for the hygienist to tell the old man, or the victim of so-called "premature senility", that he should have taken wiser care of himself during middle age or maturity. Most advice comes too late in such cases. But surely something can here be done by way of warning to the man and woman in the height of their maturity as human beings. *Now* is for them the appointed time in which, by a wise attention to the simple laws of hygiene, to avoid that artificial shortening of life and hastening of old age, in which the hygienist observes most men and women of such ages to be actively engaged.

The climacteric changes that come to physical life

Inevitably and naturally, there comes at length to both sexes a time when the part of our physical and psychical nature associated with the parental function begins to decline. This time is called the "climacteric". The "grand climacteric" was regarded by ancient authors as occurring at sixty-three in man, and that date very fairly represents the center of the climacteric period in many cases. In women, though they live longer than men, the climacteric occurs much earlier, and this "change of life" usually has much more marked characteristics and accompaniments in women than in men.

The change of life is undoubtedly a period which involves special dangers for the health of the mind in many instances. This is notably a stage in the life-history of the individual when heredity tells, and when the inheritance of nervous instability may reveal itself, perhaps for the first time. A natural tendency towards a reduction of the output of energy is perhaps the essential characteristic of the change of life in both sexes. Sir Thomas Clouston has written so wisely and with such immense experience and authority on this subject that we cannot do better than quote a paragraph from his book.

"The meaning of the climacteric biologically is clear enough. It is the departure of one great function and a slow lessening of all the others. The rules of its hygiene, therefore, must be absolutely founded on those facts. The intense energizing, the ceaseless thinking, the overdoing of all kinds of work and enjoyment, which might be allowable, if not continued too long at a time, during full manhood and womanhood, can no longer be safely practised when this period has commenced. All output must be lowered to the capacity of the producing mechanism."

The "change of life" as an introduction to a green old age

"The way in which some men and women suddenly collapse at this period, either results from bad heredity or too much over-pressure for the period, or both combined. The weak points are beginning to come out, and must be carefully considered and allowed for if the remainder of the life is to be as effective as it can be, and as happy as the lowered energies permit of. To those for whom it is possible, a distinct resting-time about this period, a change of scene, a long voyage, a deliberate slackening of business or professional engagements and a considerable change of diet are all desirable, and may make all the difference in attain-

ing that green old age which everyone would like to enjoy. To adapt, in fact, hygiene to the physiology and psychology of the period seems not only common sense, but a duty which all men and women owe to themselves. The tendency among the strong and healthy is to resent nature's sure law of decay, and to disregard her danger-signals until too late."

Wise advice for going slowly down the inevitable later slope of life

Observe that the principles which we laid down for maturity do not apply to the decadent period when maturity definitely yields place. What we said of the man of forty-five does not apply to the man of sixty-five. The strong and healthy man, with an active mind, who rightly declined to relax the strong tenor of his life in his forties, has now to recognize an inevitable fact of human life, which no resolution can alter. He must modify his behavior accordingly, and very often, if he is wise, he will find that he can adapt his mind very well to the somewhat slackened tenseness of life which the post-climacteric period demands. And the man should remember that, except in rare cases, he has less to endure at the climacteric than woman has.

The *tedium vitæ* — boredom with life — which was long ago described as the common characteristic of the climacteric, remains so to this day. Interest in life diminishes too often, "pleasures that cost little and imply small exertion are preferred to pleasures of the higher sort that need some strenuousness to attain them". The temptation towards excess of food and drink is often too strong to resist, and, as Clouston says, "many people take to alcohol then, because in them it seems to be the simplest way of reviving some of the intensities of their former lives, or of deadening the regrets which the conscious absence of these intensities creates". At the climacteric a non-stimulating diet is preferable, and it is probably well to cut down the amount of protein that has been consumed with more or less impunity in former years. Especially is this so for people in whose families there is any definite tendency towards gout or rheumatism, for this may be just the period at which such tendencies assert themselves if they get the chance. Fruits, vegetables, cereals and fish are perhaps the safest and wisest diet for the climacteric period.

The disabilities of the climacteric no cause for grave apprehension

But the mind is apt to show its weakest points at this time, just as the body is. People become the victims of obsessions of various kinds in many cases, and the reason does not seem to have its usual power of dismissing as nonsensical or trivial notions which really are so. It is against such tendencies, which may sometimes lead to actual insanity or suicide, in persons naturally predisposed towards mental instability, that we prescribe relaxation of mental strain, change of scene, attractive hobbies and so forth.

Let not the reader suppose that these various risks and disabilities of the climacteric, upon which we have insisted, are to be regarded with grave apprehension or with despair of ever emerging from them. On the contrary, the climacteric is exactly what it is called in popular language, the "change of life", and things regain a more stable state, though at a different level, when the change is completed. This is, indeed, only the obverse and correlative of that earlier period of transition which we call adolescence, and which also has its especial risks and complications. The train of events is most definite and demonstrable, as a rule, in women. They suffer far more than men at this period, and in their inexperience — for none of us pass this way but once — they often suppose that the joy of life, that everyday health and capacity for work and play, are gone forever.

But this is very far from being the case. On the contrary, the climacteric period simply offers to each woman a kind of problem which she must deal with as best she may before she can find its solution. In proportion to the wisdom, the philosophy and the common sense with which she meets this period may we expect her to find her problem solved thereafter.

Some manifest advantages of age when it is wisely welcomed

Here is Clouston's summing up:

"Nature provides that there is a period of mental peacefulness, calm and health, with even a reasonable amount of energy of the right sort in many cases, between the crisis of the climacteric and the beginning of old age. Especially in the female sex there is better health enjoyed at this nondescript period of life than has existed for twenty or thirty years previously. Many of the dangers and excitements of life have passed; its passions have abated, and the powers of judgment and control have asserted themselves over emotion and impulse. Much good work, especially of the judicial and benevolent sort, is done at this period of life. If strenuousness is not so great, caution is enormously increased. The experiences of the former life are applied in a really effective way.

Health and happiness of mind and body a continuous possibility

"Much happiness may be enjoyed if a too keen enjoyment is not expected or strained after."

With these wise and hopeful words from a veteran student of the mind, who has every kind of experience behind him, we may conclude our discussion of this subject. We have seen that there are certain natural periods of life, which we all illustrate, and to which we must all conform, until the inevitable end; but we have also seen that the honest and scientific study of these periods and their transitions may help us to protect ourselves, and so to direct our lives that we may derive the most health and happiness of body and of mind throughout every year of life, from the advent of maturity until the coming, and the passing, of a ripe and honored old age.

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THE WEALTH OF THE COTTAGE HOME — FROM THE PAINTING "MATERNITY", BY WALTER LANGLEY

GUARDING THE MARINER

How River, Lake and Sea are
Made Safe for the Sailor

LIGHTHOUSES BOTH ANCIENT AND MODERN

THE fascination of a life on the sea has ever been tempered by the fear of rockbound coasts and the dangers that lurk in hidden shoals and sunken reefs. Ever since men began to "go down to the sea in ships" the anxious watchers on the shore have tried to aid them in finding their way safely back to harbor. In early days these efforts, no doubt, often took the form of fires built on elevated points of the land, but we have poetic mention (660 B.C.) of a lighthouse of some kind at ancient Segeum, in the Troad, and this is perhaps the first maintained regularly for the guidance of mariners. The most famous of ancient lighthouses was the Pharos, which was erected about 275 B.C. at Alexandria, in Egypt, upon a small island of that name at the entrance to the harbor. It is said to have been 600 feet high but, whatever its height, it became world-famous and the name became the general term for a lighthouse. It was destroyed by an earthquake in the thirteenth century. The Romans built many light towers. One of these, a square stone tower about 130 feet high, built at least as early as the fourth century, is still standing at Coruña. The Spanish government has restored it, incased it in granite, and put it into active service again after many centuries of darkness. It is the oldest light tower in use.

All of these ancient lighthouses and many of the modern ones were situated on the land, usually on an elevation, above the reach of the ocean waves. The earliest existing wave-washed lighthouse is the beautiful tower of Cordouan, built on a rock in the sea at the mouth of the river Gironde, 63 miles below Bordeaux, France. Begun in 1584, it was completed in 1611. The original dome of the structure was replaced by a higher tower (207 feet), with the light 196 feet above high water. Up to the eighteenth century the light was obtained from a fire of oak logs, and after that from a coal fire, until it was modernized. During the seventeenth and eighteenth centuries many such towers, fitted with braziers or grates for burning wood and coal, were built on the European coasts. The first American lighthouse was built on Little Brewster Island at the entrance to Boston Harbor in 1716. It was equipped with a "great gun" to signal ships in foggy weather. The original tower was destroyed during the Revolutionary War and a new lighthouse was built in 1783. During the Colonial period ten lighthouses were erected on the Atlantic Coast. All of these have been destroyed or removed except five: those at Sandy Hook, Cape Henlopen, Portland Head, Tybee and Cape Henry. The original towers at Sandy Hook and Cape Henlopen are still in use, but the others have all been altered or are not in use. Sandy Hook is the oldest lighthouse standing in America.

Lighthouses, as we have said, may be land structures or built on rocks or shoals where they are exposed to the force of the sea. The first class may, of course, vary greatly in height and character. If the light is situated on high ground the tower itself need not be high, as illustrated by the light at Point Reyes, California, or by the light at Cape Mendocino in the same state. The tower of the latter is only 20 feet high, but it stands upon a cliff 422 feet above the sea and is the most highly elevated light in this country.

On the Atlantic coast, however, where the shore line is for the most part low-lying, the light towers of land structures must, in general, be lofty to be effective. Thus the lighthouse on Cape Hatteras is 200 feet high and is the tallest in this country. Other notable land structures are those at Cape Henry and Cape Charles, Virginia, and the beautiful tower at Pigeon Point, California. The Petit Manan light on the coast of Maine is also a handsome structure of granite 115 feet high.

Photo Boyer

PORT SAID LIGHTHOUSE
At the northern entrance to the Suez Canal

The Tillamook light off the coast of Oregon is perched on a great rock about a mile off shore and exposed to the full sweep of the ocean. The rock is high and precipitous so that landing upon it, even, is dangerous. The tower rises 136 feet above the high-water mark, yet in 1887 the sea broke over the structure and did serious damage, and in 1912 the government tender was unable to reach the rock for seven weeks on account of a violent storm. The lighthouse on St. George Reef, lying about six miles off the northern coast of California, is somewhat similarly situated. It was finished in 1892 at a cost of over $700,000, and is the most expensive structure of its kind as yet built by the United States. Many of the land structures are nothing more than substantial structures for housing the light and fog-signaling apparatus, with living quarters for the keepers and their families.

Wave-swept lighthouses are by far more interesting than land structures, perhaps because their keepers present a stronger appeal to human sympathy. There are a number of well-known lights of this character, but that on the Eddystone Rocks, 14 miles off Plymouth, England, is the most famous. This dangerous reef, which is exposed to the full sweep of the southwest seas, is submerged by the spring high tides. The first lighthouse, built in 1695–1700, was swept away in 1703 and all the occupants drowned. The second, constructed largely of wood, was burned in 1755. In 1755–59 the engineer John Smeaton built a tower of stones, the average weight of each of which was a ton, dovetailed together horizontally, and fastened with wooden pins driven into the course above and below. The present structure, which superseded Smeaton's in 1881, rests upon a base 44 feet in diameter and 22 feet high, fitted to the surface of the ledge, to which it is secured by bronze bolts. It weighs 4668 tons and the light is 133 feet above high tide. The stonework of tower and foundation is dovetailed together both vertically and horizontally. Other well-known wave-swept lighthouses are the Bell Rock and Skerryvore off the Scottish coast, and the Bishop Rock Light off the Scilly Islands.

Of American wave-swept lighthouses that on Minots Ledge off Cohasset, in Massachusetts Bay, is one of the best known. The first light on this ledge, which is bare only at low water, was supported on wrought-iron piles wedged into holes in the rock. It was completed in 1848 and was swept away by a gale in 1857, the two keepers being drowned. The present fine stone light was completed in 1860, and the undertaking ranks among the most difficult of its kind. The lower courses are carefully fitted to the rock and held down by great anchor bolts.

LOFTIEST LIGHTHOUSES OF FRANCE, ENGLAND AND THE UNITED STATES

Photos U. S. Lighthouse Service

CAPE HATTERAS LIGHT STATION, N. C.

CORDOUAN LIGHT, FRANCE

EDDYSTONE LIGHTHOUSE, ENGLAND

The tower is 107 feet high and contains accommodations for the keepers only, dwellings for their families being provided on the nearby mainland.

There are two fine specimens of wave-swept lighthouses in the Great Lakes resting on sunken ledges. Spectacle Reef lighthouse at the northern end of Lake Huron is a stone tower standing in 11 feet of water ten miles from land, and exposed to the action of heavy moving ice. To lay the foundations for this tower a great coffer-dam was built around the site and the water pumped out. The rock was leveled off and the foundations of cut stone very securely fastened to the ledge 11 feet below the surface of the water. The tower was completed in 1874 and that same winter was successfully subjected to a particularly severe test by the ice. The Stannard Rock light, completed in 1882, marks the most dangerous ledge in Lake Superior. It is 24 miles from shore, being the most distant from land of any American lighthouse. Like the Spectacle Reef light, it stands in 11 feet of water and was also constructed by the coffer-dam method.

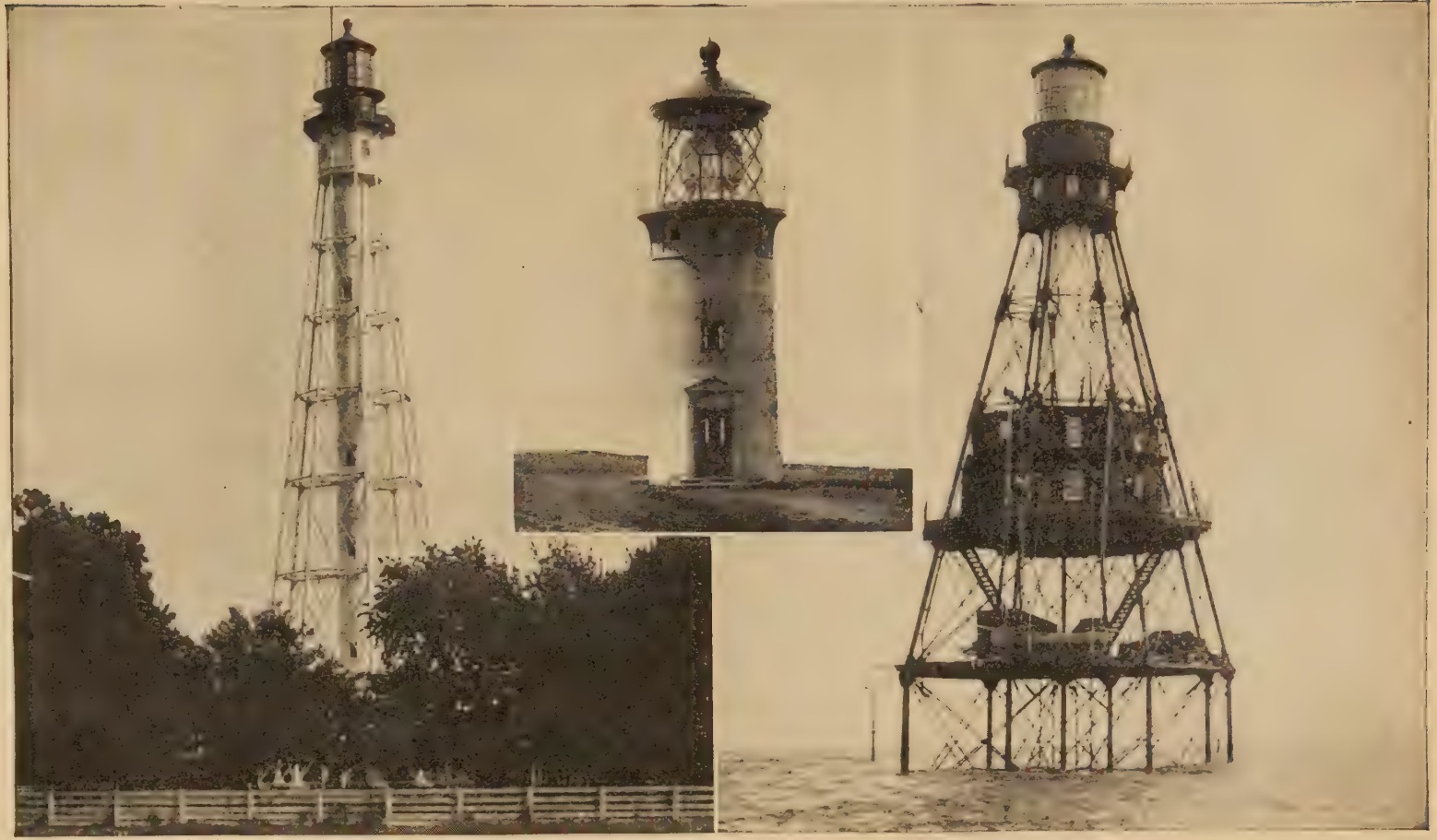
The problem of securing a foundation on a sunken sand or gravel bank is, of course, different from that presented by one on a sunken ledge of rock. The most notable construction of this kind is that on the Rothersand ten miles off the German coast in the approach to the mouth of the river Weser. This sandy bar is covered by 20 feet of water, and the first attempt to secure a footing by sinking a caisson was unsuccessful. In 1883, however, a wrought-iron caisson 47 feet long, 37 feet wide and 62 feet high was towed to the bar and sunk to a depth of 73 feet at lowest tide. Eight feet up from the lower edge of the caisson was a diaphragm which formed a working chamber. From it rose a cylindrical shaft with an air lock, so that workmen could enter and leave the working space. The sand was blown out of the bottom by pneumatic pressure and, as the caisson sank, the side walls were raised by attaching other sheet iron plates. When the caisson had been sunk to the required depth, the interior was filled with masonry and concrete and the tower built upon this foundation, further

Photo Brown Bros.

TILLAMOOK ROCK LIGHT, OREGON

This, the most important station on the Pacific coast, is an example of a square built lighthouse. Thirty feet of the rock's crest were blasted off to provide a sound foundation, and this gave space for ample quarters for the men. The rock is so lonely and so difficult of access in bad weather that four men are always stationed there. The lantern was once smashed and the light extinguished by a mass of rock which was torn from the islet and flung by the waves on top of the dome.

THREE TYPICAL STYLES OF LIGHTHOUSE CONSTRUCTION



Photos U. S. Lighthouse Service

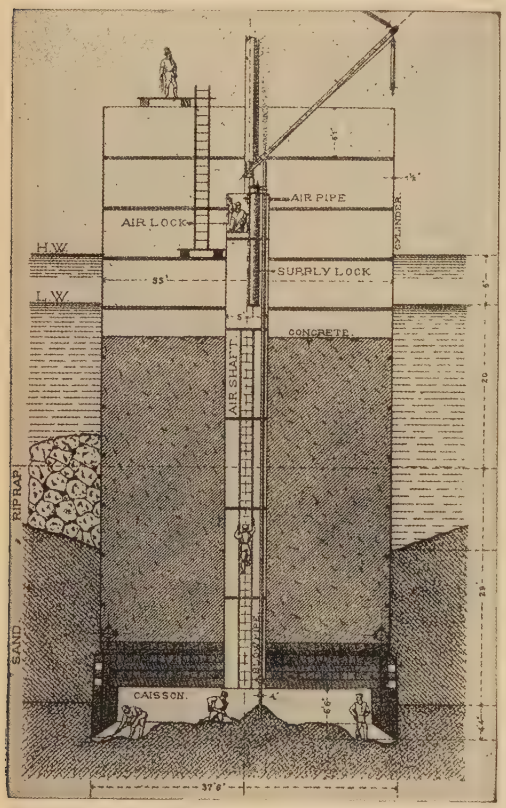
CAPE CHARLES LIGHT STATION, VA.

KILAUEA POINT LIGHT STATION, KAUAI, HAWAII

AMERICAN SHOAL LIGHT STATION, FLA.

protected against the shifting of the sand by sinking a large quantity of stones around it. The tower is an iron structure carrying a light 78 feet above high water, operated by electricity through a submarine cable from the adjoining mainland.

The lighthouse on Fourteen-Foot Bank in Delaware Bay was also built in this manner in 1887. Here, however, the caisson was constructed of timber with an iron cutting edge seven feet deep. On



The lighthouse on Fourteen-Foot Bank in Delaware Bay rests on a great concrete pillar. This illustration shows how the steel shell was sunk in the sand by the caisson method.

this raft-like structure was placed an iron cylinder 35 feet in diameter and 18 feet high and the entire outfit was towed to the site and sunk by letting water in. When well bedded down into the sand the lower chamber was cleared of water and the sand removed by digging and blowing it out through a pipe. The sides of the cylinder were raised as the structure sank, and the interior was filled with concrete. An attempt to secure a foundation on the Diamond Shoals off Cape Hatteras by this method proved unsuccessful because of the force of the waves and the strong ocean currents.

The problem of securing a foundation on sandy bottoms has been solved in some cases by what is known as "screw piles". These are stout iron legs with a large thread on the lower end and can be literally screwed into the sandy floor of the ocean, thus providing legs or stilts on which to build the lighthouse. The first structure of this kind to be built in the United States is that on the Brandywine Shoal in Delaware Bay and it stands in six feet of water.

Unlike lighthouse towers which rest upon stone foundations and which usually are now constructed of stone, brick or reinforced concrete, towers that rest upon screwed piles are made of structural steel in order to secure strength and lightness. The Point Arena lighthouse in California was the first tower in this country to be made of reinforced concrete and this form of construction was used for the lighthouses along the Panama Canal. The United States has also completed a fine lighthouse of reinforced concrete on Navassa Island between Haiti and Jamaica. This rocky islet stands right in the natural passage on the way to Colon at the entrance to the Panama Canal and was a great menace to navigation. The fine tower, which has been built with special care to withstand the violent hurricanes that prevail in this region, is 150 feet high. The light is of 47,000 candle-power and has a radius of 29 miles. Its flashing rays sweep a sea area as large as the state of Delaware.

All important lighthouses such as have been described must have constant attention, and from one to five keepers are always in attendance. In many cases provision is made for their families in comfortable houses near the towers. In addition to these major lights there are many minor lights, particularly on inland waters, that do not require a resident keeper, but are cared for by some person living in the vicinity, and who may not devote all his time to one light but may care for several.

In recent years many lights have been installed in lonely or inaccessible places which need attention only at long intervals, some of them as infrequently as once in five months. These lights are operated by gas stored under pressure or by acetylene gas generated from carbide at the station. Some of the latter have peculiar and interesting automatic valves operated by sunlight. When the sun shines the valve closes, thus saving gas during that period. Lights of this nature have been found very useful and inexpensive in Alaskan waters in places where it would be inhuman to ask a keeper to live. In addition to these "lighted aids" to navigation there are many unlighted aids, or "daylight beacons", to aid the mariner, especially in inland navigation. These may be simply a small structure on a headland, painted white so as to be more easily visible, or they may be something more elaborate. Such landmarks are, of course, noted on the charts used by navigators and fully described in nautical literature.

Photo G. & R. Lavis

BEACHY HEAD LIGHTHOUSE

Photo Brown Bros.

MINOTS LEDGE LIGHT

The most interesting thing about a lighthouse is, of course, the light itself. The first lights, as has been mentioned, were simply open wood or coal fires in braziers on the top of the towers. These in time gave way to oil lamps inclosed in rough glass cases. Thus when Boston Light

was built, in 1716, fish or whale-oil was burned in crude lamps with solid wicks and the lantern was made of wooden frames holding small, thick panes of glass. Rough reflectors were sometimes placed back of the lamps and a rough lens or "bull's eye" was used to condense the rays to some extent. The first great improvement was the introduction of a reflector made with a parabolic cross-section, which has the peculiar property of reflecting all the rays of a light placed in principal focus, in parallel lines. Rays thrown from such a reflector form a beam of light and are not distributed in all directions. No condensing lens was needed. To provide illumination around the entire horizon several lamps were used with a separate reflector placed back of each. As high as twenty lamps were thus used in some lights in this "catoptric" or "reflector" system, as it was called. The great light on Heligoland is equipped with three arc lamps backed by parabolic reflectors.

Photo U. S. Lighthouse Service

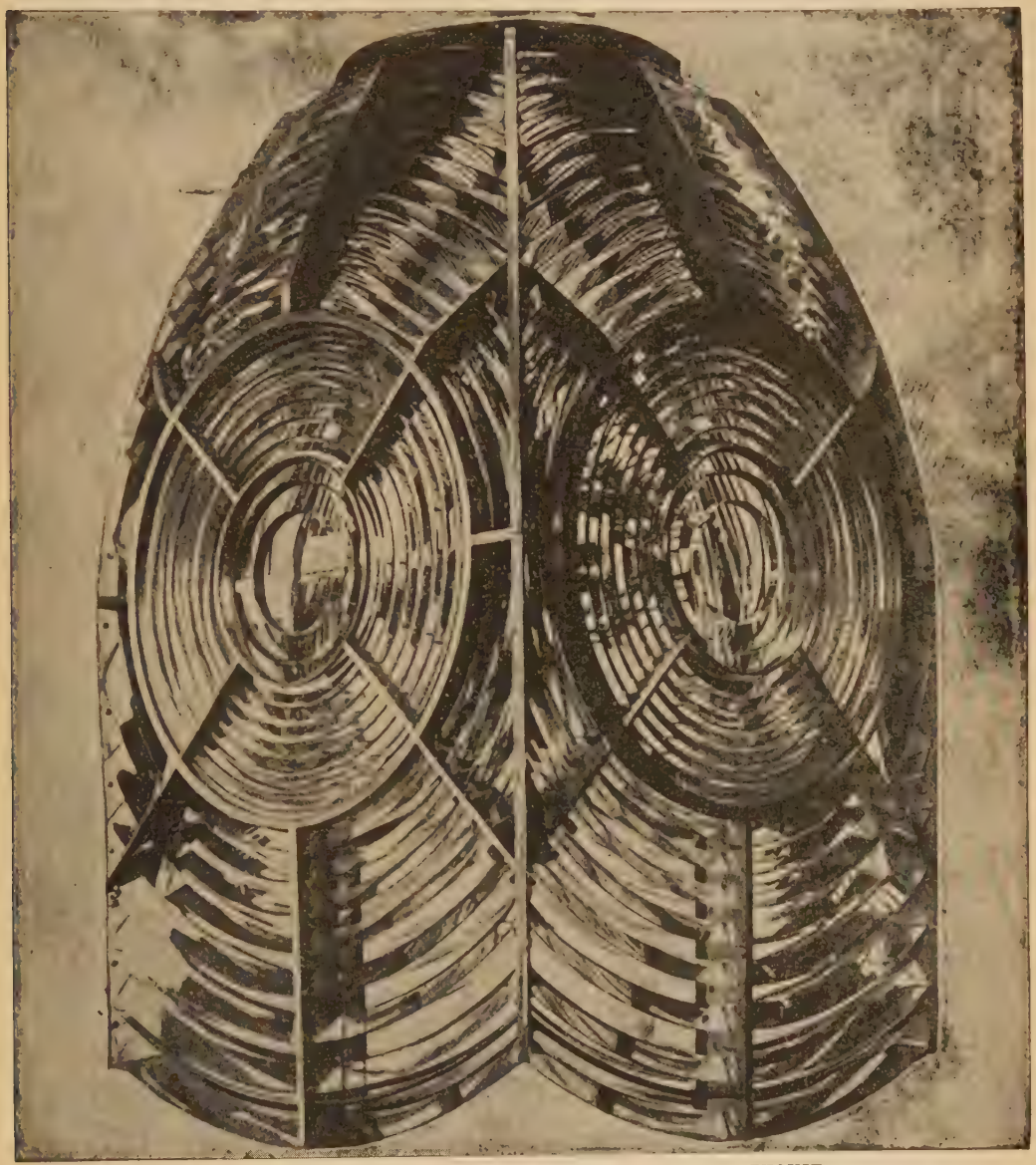
POINT REYES LIGHT STATION, CALIFORNIA

About 1822 a French physicist named Augustin Fresnel revolutionized lighthouses by his invention of a new system of lenses, refractors and reflectors of glass which surrounded a single central lamp. This apparatus is well described as consisting "of a polyzonal lens inclosing the lamp which is placed at the central focus. The lens is built of glass prisms in panels, the central portions of which are 'dioptric' or refracting only, and the upper and lower portions are both reflecting and refracting, described as 'catadioptric'. The advantages of this system lie in the greater brilliancy owing to the fact that a large proportion of the light given out by the source is concentrated by the prisms into beams useful to the mariner and the consequent economy in the consumption of oil or other illuminant employed." A Fresnel lens of the most complete type renders effective about 60 per cent of the light generated, the remainder being lost at the top and bottom of the lantern and by being absorbed by the glass of the lens. Fresnel lenses are classified according to their size or order, this size being measured by the distance from the center of the light to the inner surface of the lens. Thus in a "first order" light this distance is 36.2 inches, in a "second order" light 27.6 inches, and in a "sixth order" light 5.9 inches.

The first Fresnel lens was installed in this country in 1841 at the Navesink light at the entrance to New York Bay. The largest lens owned by the United States is at Makapuu Point, Oahu, Hawaii, and is the first light to welcome the mariner approaching these islands from the United States. It is larger than those regularly listed as of first order, being 52.4 inches in radius. The inside diameter of the lens is therefore nearly nine feet and it is inclosed in a special lantern of sixteen feet inside diameter. A Fresnel lens of large size is a very beautiful object; the highly polished lenses with their brilliant reflecting surfaces neatly set in the great metal frame give it the appearance of a great jewel.

In order to make it easy to identify one light from another, distinguishing charac-

teristics are given peculiar to each. Color distinctions are sometimes used for minor and for short range lights, the lenses being usually red. There is, however, a great loss of light in colored lenses; in red, which are the most efficient, 60 per cent. In many cases a fixed light is all that is necessary, though the danger of confusing it with other lights on shore or on vessels is against it. In such lights the construction consists of a central lamp and a lens that will spread light over as much of the horizon as is necessary. More important lights, however, are of the "flashing" or of the "occulting" type. In the former the entire lens is made to revolve, the beam from each panel of the lens appearing as a flash to the eye of the observer. In order to obtain smooth and rapid motion the entire lens is mounted on a mercury float, lenses weighing as much as seven tons thus making a complete revolution in half a minute. The lens at Kilauea Point, Hawaii, made in France at a cost



THE MANY-PRISMED LANTERN OF THE MODERN LIGHTHOUSE

of about $12,000, weighs four tons. It is mounted on a mercury float and makes a complete revolution every 20 seconds, giving a double flash of about 940,000 candle-power every 10 seconds. The double flash is obtained by placing two lenses on one side of the axis and two on the other, arranged symmetrically. Obviously, a great variety of signals can be arranged by varying the arrangement, shape and color of the lenses.

In occulting lights, which are less efficient than flashing lights, the lens is usually stationary and a moving screen or shutter outside it obscures the light at regular or irregular intervals; but when gas or electricity is used the break is made by cutting

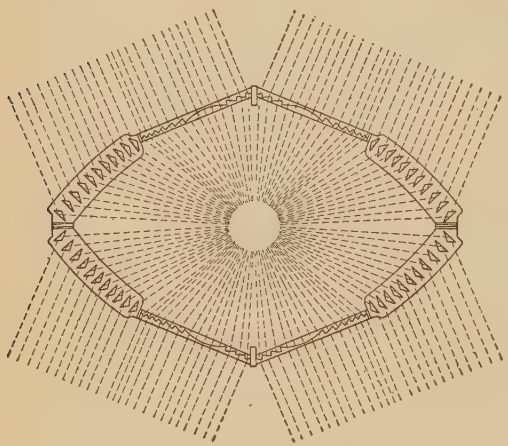


DIAGRAM SHOWING ARRANGEMENTS OF PRISMS IN THE LENS AT KILAUEA POINT

off the supply of gas or current. In both cases the mechanism for obtaining the characteristics is controlled by some automatic device which insures great exactness in the sequence of the periods of light and darkness.

The lights in the early lighthouses were supplied with whale-oil and later, as this oil became more expensive, with lard oil. When kerosene came into use about 1880 it was quickly adopted for lighthouse use and in a few years it became, and remains, the principal illuminant. The lamps also have been greatly improved, the present form using concentric wicks, some of them as many as five, so as to bring air into the middle of the flame, on the principle of the Argand burner. Some of the more important lights now burn oil vapor, under an incandescent mantle similar to that used over domestic gas jets. Air is forced into a tank by an auxiliary hand-pump and the pressure so produced forces the oil into the preheated vaporizer of the lamp. The vapor issues from a nozzle, mixes with the proper proportion of air and burns with a blue flame like that of a Bunsen burner, heating the mantle to incandescent heat and producing a very brilliant light. Other illuminants, such as acetylene, coal-gas, incandescent electric lights and arc lights, are also used to a limited extent, but the report of the U. S. Lighthouse Service for 1915 shows that 2067 kerosene lights were in use out of a total of 3355, and more recent reports indicate a tendency to extend the use of this illuminant.

The unit by which the brightness of lamps is measured is "candle-power", that is, the illuminating power of a spermaceti candle burning at the rate of 120 grains of sperm per hour. The early lights were, of course, of low candle-power, not at all comparable with modern equipments. In 1915 there were 42 lights in the U. S. Lighthouse Service that were over 100,000 candle-power, 19 that were over 200,000 candle-power, and nine of over 300,000 candle-power. The Molokai light, Hawaii, is 620,000 candle-power and the great Navesink electric light, the brightest in the world, is 25,000,000 candle-power. This light itself can be seen at a distance of 22 miles, but its glare is visible 70 miles at sea. The light on Cape Mendocino, the highest in the service, standing 422 feet above mean high water, can be seen 28 miles; and the new light on Kilauea Point, Hawaii, the landfall light approaching the islands from Japan, is 940,000 candle-power. The most powerful light on the North Sea coast is that on the island of Heligoland. The lamps are electric arcs and are said to be 38,000,000 candle-power. The focal plane is 269 feet above the water.

All the nautical safeguards so far discussed are known as "fixed aids" to navigation. There are many places, however, where such are either not desirable

or not feasible and more than one-half of the aids maintained by our government are of the floating type: light-ships, buoys, spars, etc. The first light-ship in English waters was the *Nore*, placed at the mouth of the Thames in 1732. The first in this country was anchored at Willoughby Spit, Hampton Roads, Chesapeake Bay, in 1820. The first outside vessel was stationed seven miles off Sandy Hook in 1823. The dangerous Diamond Shoal, off Cape Hatteras, was marked in 1824, but the vessel was driven ashore in 1827 and no ship was again anchored there until 1897, after the unsuccessful attempt to build a lighthouse. This and the light-ship on Nantucket Shoals, for which most transatlantic steamers steer in approaching America, are of the greatest importance to mariners on the Atlantic coast.

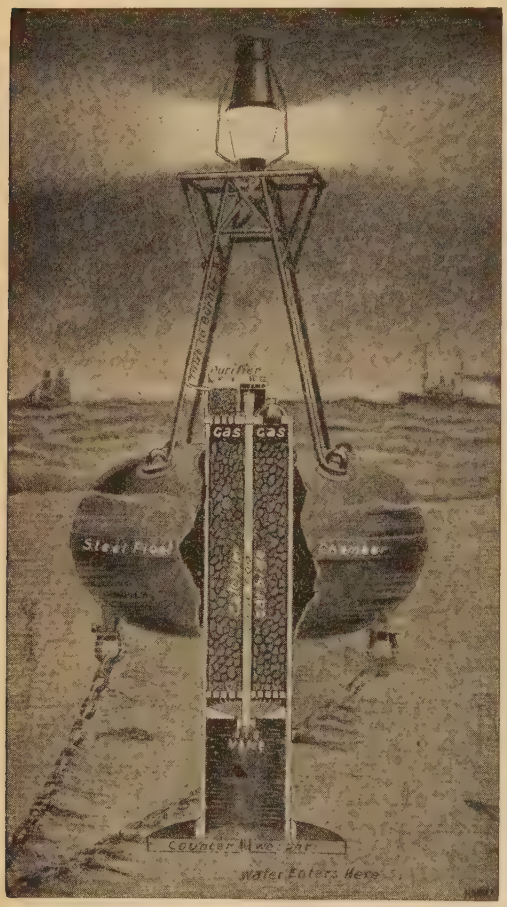
Photo U. S. Lighthouse Service

DIAMOND SHOAL LIGHT-SHIP

The first light-ships were small wooden vessels carrying a fixed light on a mast, a bell and a fog-horn, both of the latter operated by hand. In the beginning they often broke from their moorings and came ashore, endangering the lives of the crew and making the service unreliable. The modern light-ship is a steel vessel of possibly 700 tons, equipped with propelling machinery, securely anchored to a 7500-pound anchor by a great iron chain, the links of which are made of bars $1\frac{5}{8}$ inches in diameter. They are equipped with a hollow mast, which carries the light and gives access to it, and have power-operated bells or fog-horns. In the latest models the light is a revolving one, supported like a pendulum, so that the beam is always horizontal regardless of the motion of the vessel.

The newest and largest light-vessel in the U. S. Lighthouse Service, No. 105, which is stationed on the dangerous outer Diamond Shoal off Cape Hatteras, replaces the one which was sunk by the guns of a German submarine on August 6, 1918. She shows a flashing light from a lens lantern at the foremast head, the illumination being acetylene gas, controlled by an electric flasher operating the gas burners, and giving the light a characteristic distinguishing it from other lights on the neighboring coast. The vessel is 147 feet in length, has a displacement of 825 tons,

and is driven by a compound engine with an indicated horse-power of 400. She is equipped with three distinct fog signals, a steam chime whistle, a submarine bell and an automatic fog signal, and is the first light-ship to be equipped with the radio signal. When a light-ship is under repairs her place is taken by a relief ship which may not have the same characteris-



PICTURE-DIAGRAM OF GAS-LIGHTED BUOY

The sea water passes through a controlling valve into a cylinder filled with calcium carbide, and combines with it to form the gas, which passes out through a purifier into the feed-tube of the lamp.

tics, and due notice of such a substitution is made in the nautical news published for the guidance of mariners. The crew of a light-ship consists of from three to ten men, depending on the size of the vessels and the nature of the service.

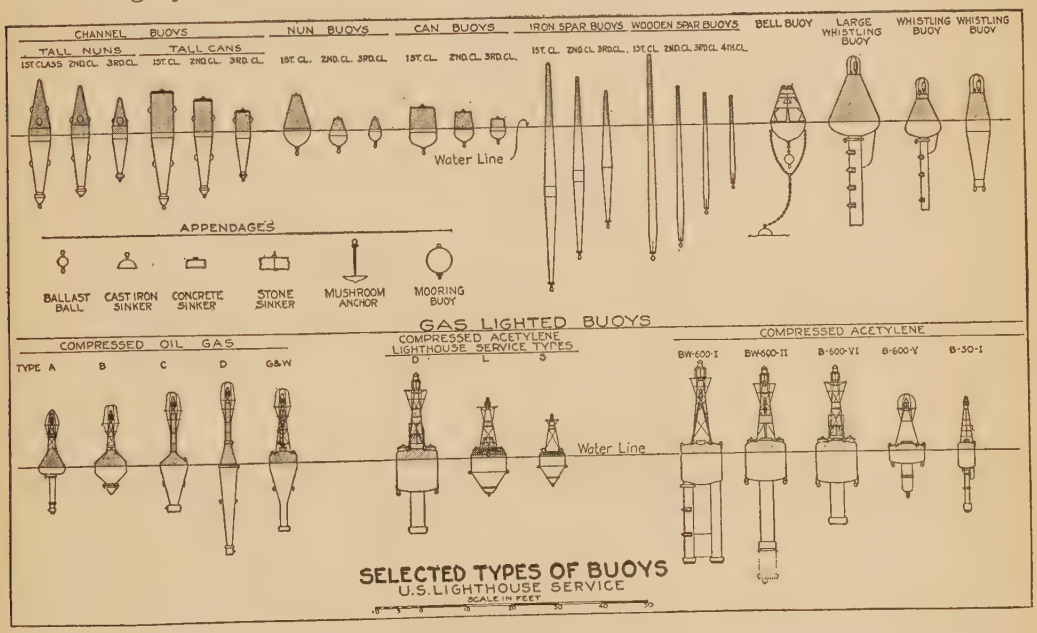
Just as there are unattended aids on land so there are unattended floating ones. Recently an unattended light-ship has been stationed off the coast of England. It has no crew but is equipped with a flashing gas light and an aërial and a submarine fog-bell which are operated by the motion of the sea. The great majority of unattended floating aids, however, are of the buoy or spar type. The accompanying illustration shows a variety of those used in this country to mark dangerous rocks or shoals, to indicate the lateral limits of navigable channels or the approaches to channels. In their simplest form they consist of wooden or iron spars moored by one end so as to stand almost vertically. In more elaborate form they are hollow tanks of such shapes as will float in a fixed position, painted a distinctive color and numbered in large-sized figures so as to make identification easy.

The more important buoys are fitted with bells or whistles so as to be effective in foggy weather. The bells, usually provided with several clappers, are actuated by the rolling motion of the buoy. The whistling-buoy carries a long vertical tube which is closed at the upper end by a plate fitted with a check-valve which will admit air as the buoy rises on the waves but closes when it tries to escape as the buoy falls. The escape of the entrapped air is through the whistle, so that the buoy itself constitutes an automatic air-pump. Like the bell-buoy, the whistling-buoy is effective only when there is wave disturbance, and they are not to be depended upon for signaling in the fog in quiet waters.

A number of important buoys, instead of bells or whistles, carry lights operated by some kind of gas compressed into the body of the buoy which acts as a container. Buoys lighted by electricity carried from the shore by means of a cable, and those lighted with acetylene gas generated from carbide and water within the buoy, have been tried but without success. In its most highly developed form the buoy carries a flashing light, the mechanism for operating which is actuated from the compressed gas in the buoy itself. The buoy at the entrance to the Ambrose Channel in New York Harbor shows a light of 810 candle-power every 10 seconds, 27 feet above the water, that can be seen for ten miles. It will burn for over a

year without recharging. This buoy is 60 feet long and weighs 17 tons. Some buoys not only show a light but are also equipped with a bell or whistle and a few have both a whistle and a submarine bell.

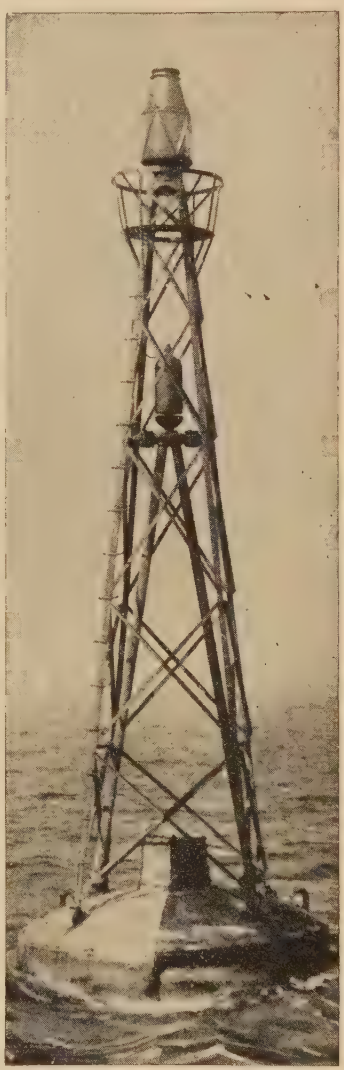
All lighted aids are, of course, ineffective in thick fog or rain, and a number of sound-making devices have been contrived to supplement them at such times. The cannon that stood beside the first Boston Light indicates one of the first steps taken in this direction, and improved explosive signals are still in use in Europe. Bells were introduced at an early date, at first rung by hand, then by clockwork



or other governing mechanisms, which would strike a regular code of signals. Bells weighing 4000 pounds are now in use for this service. Then came the reed trumpet, which is something like an organ pipe with a large resonator attachment. The compressed air for its operation was first obtained by horse-driven, later by gas-driven, machinery. The trumpets were soon found inadequate for outside stations where very heavy weather is encountered, and steam whistles were tried. The first regular installation of this kind was at Cape Elizabeth, Maine, in 1869, and consisted of a boiler with a 10-inch whistle of the locomotive type. The expense of operation and that due to the deterioration of the boiler, and the time required to get the whistle working are serious disadvantages in this type of apparatus, and while still much used in this country it has been practically abandoned abroad. Experiments were next made with what is called a "siren". This instrument in its simplest form consists of two discs, one fixed and one revolving, pierced with a number of holes arranged in a circle. When air or steam strikes the discs at a point where the holes are opposite each other, its escape from the twin opening makes a sound. The faster the revolving disc spins, the more continuous the sound and the higher its pitch. In modern sirens the discs are superseded by cylinders and compressed air is usually employed, the air compressors being often operated by gas-engines. In the automatic siren the rotating cylinder is turned by the jet of air or steam, in the other by an independent mechanism. The great advantages of the compressed-air siren are the distinctiveness of the note, and the ease and quickness with which it can be brought into action, especially when operated by a gas-engine. An electrically driven blower siren is known as the "sireno" and another variation, called

the "diaphone", employs a reciprocating piston in the fixed cylinder instead of a rotating cylinder. The diaphone has come into extended use in Canadian lighthouses. All first-class lights are now supplemented by a fog-signal of some kind and a well-equipped station requires considerable machinery. All apparatus must be duplicated, to insure against accident, and the engines are as much as 20 horse power. Practically all good fog-signals are provided with a controlling mechanism to insure that the strokes on the bell or the blast of the horn are repeated in a fixed and definite cycle, so as to make identification of the station easy.

But however reliable fog-signals may be, they are subject to some uncertainty from the irregular conveyance of sound in the atmosphere, which prevents the mariner from exactly judging distances. One of the most curious of these aberrations is the way in which sounds skip: they may be heard near their source, lost again a short distance away, and heard again at a greater distance. That is, silent zones or areas may exist. This phenomenon was noted in connection with the sound of heavy artillery firing during the Great War. It cannot, therefore, be assumed that mariners will invariably hear a fog-signal when within the range of its audibility, nor can it be safely assumed that fog-signals are not working because they are not heard. If the ship is in a zone where the sound happens to be faint the normal noises of the ship may interfere. Mariners therefore use extra precautions when navigating in foggy weather. Whistling-buoys and fog-horns have a mournful note that is often very annoying to shore-dwellers. But it is sweet music to the ear of the anxious mariner cautiously feeling his way through the fog toward a safe anchorage, and it should be remembered that foggy weather prevails in many places for a good portion of the year. At Seguin Island, Maine, in 1907, foggy weather prevailed for 30 per cent of the 365 days; at Calumet Harbor, near Chicago, in 1913, for 20 per cent; and on the San Francisco light-ship such weather was recorded for 24 per cent of the year 1915.



A FLOATING GAS BUOY

Of late years submarine signaling has received considerable attention. It has long been known that sound is transmitted through water more uniformly and more effectively than through air. Submarine bells have been in use in this country since 1906. The bell, which is specially constructed, is suspended from a light-ship and operated by compressed air, or it may be mounted on a frame which rests on the bottom and be operated by electricity transmitted by cable from shore. Sometimes submarine bells are attached to buoys carrying a large fin which, moved by the waves, winds up a heavy spring that in turn operates the bell hammer.

The receiving apparatus consists of a small tank of water placed on each side of the ship near the bow and made fast to the inside skin of the vessel below the water-line. Each tank is fitted with a specially constructed microphone, that is, a sort of telephone receiver which is very sensitive and which detects very faint sounds. Wires can be carried from the microphones to the bridge and connected to telephone receivers. By listening alternately to the sound coming from the

microphones the officer on duty is able to detect the direction of the signal bell with reference to the course which the ship is steering. Great advances were made in this art during the Great War when the detection of direction of sound under water was used for the purpose of locating submarines. Submarine bells have now been heard 30 miles away and there would appear to be promise of even better results. Experiments with a high whistle-like under-water note of a vibrating steel plate have developed a much greater range. Morse code messages may be sent this way.

Three radio fog-signal stations, the first of this kind in the United States, were placed in commission in 1921 by the Lighthouse Service in the vicinity of New York, at Fire Island, Ambrose Channel and Sea Girt. Important points along the coast are equipped with apparatus for sending radio signals of simple and definite characteristics during the continuation of fog or thick weather, by means of which the navigator of any vessel provided with a radio compass may, although no object is visible, take definite bearings to guide or locate his ship. The most valuable use

Photo U. S. Lighthouse Service

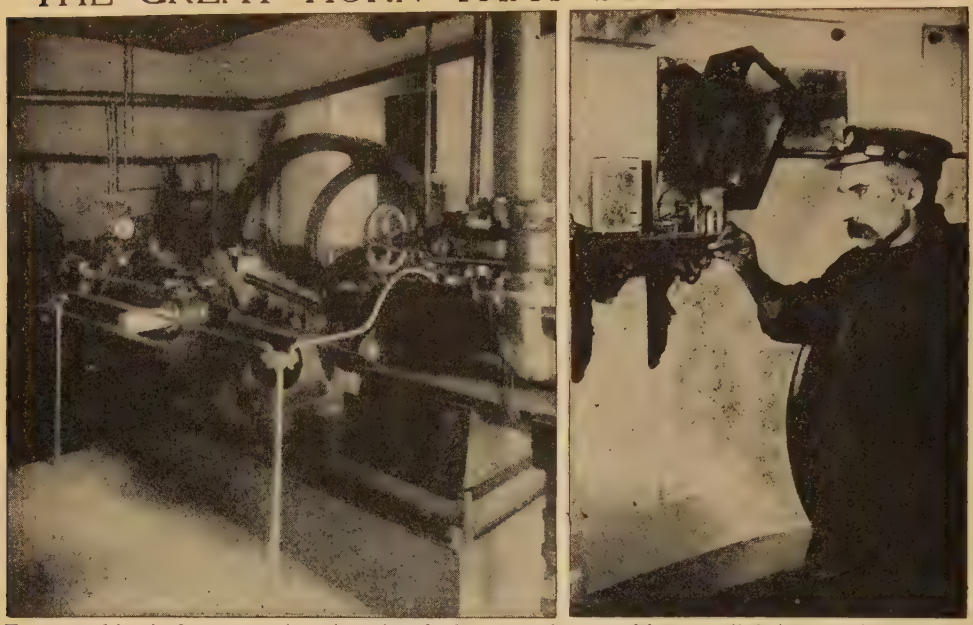
DETROIT RIVER LIGHT STATION, SHOWING FOG-SIGNAL

Perhaps the most important aid to navigation that has yet been invented is the wireless telegraph. So great is its proven worth that practically all sea-going vessels of any importance are now equipped with both receiving and sending apparatus, and many important rescues have already been accomplished by its aid. With a wireless outfit a ship can keep in communication with land and with other ships so equipped while crossing the ocean, can report its whereabouts in time of need and signal for help. Wireless telephony has lately added its convenience and extended its scope.

of the radio fog-signal will probably be as a leading mark to enable a vessel, for example, to make a light-ship marking the entrance to a harbor or to pass outside of a light-ship anchored to guard against coast dangers. This system for the first time in navigation affords a practical means by which the navigator can take reasonably accurate bearings on fixed beacons which are not visible.

All modern maritime nations accept the necessity of properly lighting their coasts, and while much has been done there is much more to do. The U. S. Commissioner of Lighthouses, writing in the *Geographic*

THE GREAT HORN THAT SOUNDS AT SEA



To warn ships in foggy weather there is a foghorn, or siren, and in some lighthouses three great gas-engines like that on the left are used to blow the horn. The man on the right is recording the time during which the foghorn is sounded.

Here is a monster foghorn for a lighthouse, one of the largest size that is made. It can be heard for miles, and is built upon an elaborate scientific principle. The horn itself is, of course, an amplifier to increase the sound made by the siren.

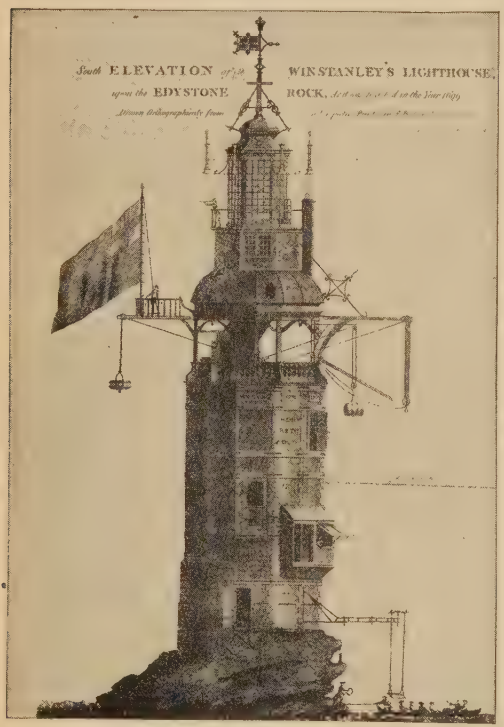
RELIEVING THE MEN AT A LIGHTHOUSE

Life on a lonely lighthouse is very dull, and the men look out keenly for the approach of the relief ship.

The ship is unable to approach very near to the rocks, and the men have to row from the ship to the lighthouse.

When the boats get near the rock on which the lighthouse is built, it is often impossible for the men to land in the ordinary way, and they have to be hauled up, as shown in this picture. In stormy weather this is very dangerous.

Magazine in 1913, quoted a British authority as giving the total number of lighthouses and light-ships for the entire world as 11,600, of which 8900 are on the coasts of Europe, the United States and Canada. South America had only 300 lights, and Africa 500. When we examine the work of our own Bureau of Lighthouses we can be proud of what it has done and is doing. Under the U. S. Lighthouse Service all the territory of the United States and its dependencies is divided into 19 lighthouse



First Eddystone Lighthouse finished in 1699 and swept away in 1703. From an old print.

districts, each district being in charge of a lighthouse inspector. In each district there are one or more lighthouse depots and a technical and clerical staff for carrying on the work of repairs and of distributing supplies and apparatus. At Staten Island, New York Harbor, there is a general lighthouse depot where many of the supplies for the entire service are purchased, stored and distributed. Each district is provided with one or more lighthouse tenders for distributing supplies and for general use in transporting materials for new construction and repairs and for caring for the buoys and other aids to navigation within the district. These tenders are power-vessels driven by steam or gas-engines of from 30 to 1700 tons displacement. They are, of course, specially fitted for this work. In 1917 this fleet numbered 50 vessels of all sizes. From the nature of the service required of these vessels they must be built unusually strong and they must be very seaworthy, as they are called upon to keep to sea in the face of the most violent storms. It is a service that calls for both bravery and skill in no small degree.

Some idea of the size and scope of the work of the department can be gathered from the official report for 1915, which lists the following aids to navigation:

LIGHTED AIDS

Major lights	1662
Minor lights	2837
Light-vessels	53
Gas buoys	479
Float lights	124
Total	5,155

UNLIGHTED AIDS

Fog-signals	527
Submarine signals	80
Whistling-buoys	86
Bell-buoys	237
Other buoys	6488
Day beacons	2001
Total	9,419
Grand total, aids to navigation	14,574

In 1917 this total had risen to 15,223, according to the official reports. In 1790 there were only 107 such aids recorded and as late as 1850 the number had only risen to 1536. Progress since that time, however, has been very rapid.

The cost of maintaining the lighthouse service is considerable. The official report for 1917 shows that Congress appropriated $5,338,680 for maintenance and $1,279,300 for improvements, or a total of $6,617,980, for the year 1918, and the corresponding total estimates for 1919 call for $8,727,830. The total number of employees in the service in 1917 was 5796. The cost of equipment is also considerable. Lighthouses with quarters for the keepers, and equipped with fog-signals,

cost from $40,000 to $200,000 apiece, and one at least, that on the St. George Reef, cost $700,000. An average-sized tender costs $150,000. Lighted buoys cost from $800 to $5000 each, whistling-buoys about $500 each, and bell-buoys about $400 each.

The personnel of the Lighthouse Service deserves special mention. Much of the work is not only arduous but dangerous. It is a life of constant watchfulness to keep the service perfect, for should even a minor aid fail to function for a few minutes it may mean the loss of human lives, to say nothing of property. Because of the remote location of many lighthouses, living quarters are provided for the keepers and their families and an effort is made to make them comfortable.

But even with all that has or can be done, the life of the keepers of an off-shore light or light-ship is somewhat dreary, though not always monotonous. This is particularly true on such light-ships as the Nantucket or Ambrose Channel that are right in the line of steamship traffic and where the danger of collision is great in times of fog. And aside from the actual danger, life in a vessel anchored in the open sea cannot be very comfortable. Of course there is always plenty of work to be done, meals to be cooked, lamps to be cleaned and trimmed, lenses to be polished and minor repairs, painting, etc. to be attended to. If it were not for such duties life would be unbearable, and as it is a very liberal provision is made for shore leave or similar absence from duty where the station is an isolated one.

It may be that as science advances improved methods of signaling will make lighthouses and light-ships unnecessary and, like the picturesque sailing vessel or "wind-jammer", they will be numbered with the things of the past. They will not, however, disappear without universal regret, for there is something human and friendly in the flash of a great lighthouse that the wireless message can never possess. And because lighthouse keepers have been faithful to their trust the lighthouse has become symbolic of all that is steadfast, helpful and enduring.

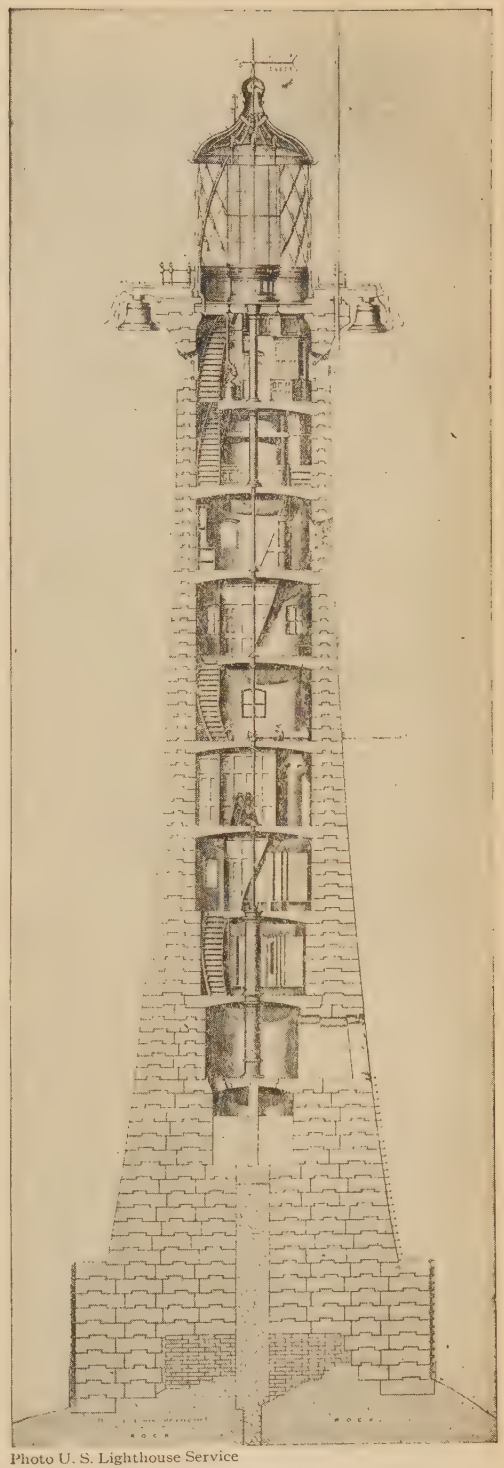


Photo U. S. Lighthouse Service

EDDYSTONE LIGHTHOUSE, SECTIONAL VIEW

This is a cross section of the present (third) structure shown on page 4687. Note the vertical dovetailing of the stonework in tower and foundations.

"THE LITTLE OLD LADY OF THREADNEEDLE STREET"

© Ewing Galloway, N. Y.

THE BANK OF ENGLAND

DEAR AND CHEAP MONEY

The Bank of England and the Mechanism of the London Money Market

HOW THE FOREIGN EXCHANGES OPERATE

THE Bank of England, today the most famous financial institution in the world, had a curious origin. At the end of the seventeenth century, when, as had often been the case before, England was engaged in a war with France, and when James II had but recently fled across the seas, the throne of William and Mary rested upon the support of the Whigs. The prosecution of war with France, the backer of the Stuart pretenders to the throne, called for money, and where was money to be had? It was in these circumstances that a company of Whig merchants of the City of London conceived the idea of forming a limited liability company to lend money to the government. At that time, of course, trading with limited liability was a rare thing, and the royal charter of 1694, which was issued by William III, establishing the "Governor and Company of the Bank of England", conferred an exceedingly valuable privilege.

The company or society thus named raised the sum of £1,200,000 (equivalent to about $6,000,000) by tempting the public with interest at 8 per cent, and so it came about that William III got his money for the war with France, the English National Debt began, and the "Old Lady of Threadneedle Street" was born. The whole of the money raised went to the government, and the company was given power to issue bank-notes for an equal amount, government security being thus behind the notes.

Not very long after its incorporation the bank was given a monopoly of joint-stock banking by a law which forbade other banking firms to have more than six partners. This monopoly was not canceled until more than a century later, and during the long interval banking was necessarily confined to the operations of private firms. In 1826 this law was repealed, but even then the Bank of England was given the exclusive privilege of issuing bank-notes within a radius of sixty-five miles of London.

The original loan of £1,200,000 was soon increased, as we may easily imagine. The Bank of England lent £11,015,100 to the State, and up to this sum it possessed the right to issue bank-notes upon government security. Beyond this it could issue notes upon its own private security. The original government debt of £11,015,100 remains to this day, and still figures in the weekly banking return of the Bank of England.

In 1844 the Bank Charter Act was passed to revise the conditions of note issue, to substitute Bank of England notes for the note issues of other banks, as far as possible, and at the same time to make the Bank of England note absolutely safe by insuring that it should be backed either by government security or actual gold.

The Bank Charter Act of 1844, commonly referred to as "Peel's Act", was the final outcome of a long controversy between the advocates of the so-called "currency" and "banking" schools, which had begun in the period of the Napoleonic wars, when the Bank of England had suspended specie payments, and when its notes, issued in large quantities, were at a discount as compared with gold. The act of 1844 embodies the "currency"

principle, which is to the effect that a country needs a certain amount of money and no more and that, since bank-notes serve as money, their quantity should be definitely fixed by law. The gist of the "banking" principle is that the amount of money a country needs depends upon the volume of trade and that there can be no overissue or inflation of bank-notes so long as they are put into circulation to finance actual commercial transactions. The federal reserve system of the United States, like the banking systems of France and of Canada, embodies the banking principle.

The bank, in accordance with the act of 1844, has two distinct departments: the issue department, solely concerned with the issue of notes, and the banking department, which handles the ordinary business of banking. The workings of this system at the present time are clearly shown in the accompanying bank statement or "return" for January, 1924. The original government debt of £11,015,100 is held as an asset by the issue department to secure an equal amount of notes. "Other securities" are held to cover notes issued by the bank as heir to part of the privileges of note issue formerly enjoyed by certain other banks. But the bulk of the notes issued are covered pound for pound by deposits of gold coin and bullion with the issue department. The so-called "uncovered issue" is thus absolutely fixed in amount. Aside from this fixed amount, Bank of England notes are precisely like the gold certificates issued by the government of the United States. The amount in circulation will depend merely upon the extent to which paper money, rather than gold, meets the convenience and preferences of the community. When gold is needed for export, or for other purposes, notes will be presented at the bank and the gold withdrawn.

Before the war any person could go to the Bank of England and demand Bank of England notes in exchange for gold at the rate of £3 17*s.* 9*d.* per ounce. An ounce of gold, as we have already seen, really makes £3 17*s.* 10½*d.* in English money, but the Bank of England is compelled to pay gold for its notes on demand, while it, in turn, has to wait for its coins when it takes gold to the mint. The margin of 1½*d.* per ounce is therefore partly interest and partly a commission paid to the bank as official agent for English gold money. When urgently in need of gold, however, the bank often raises its buying price somewhat above the legal minimum. The reader who has followed our account of the defects of the national banking system of the United States and of the improvements embodied in the federal reserve system will wonder just how under the handicap of an absolutely inelastic system of note issue the London money market has been able to achieve and retain its position of predominance.

BANK RETURN: JANUARY 9, 1924

ISSUE DEPARTMENT

RESOURCES		LIABILITIES	
Government Debt	£11,015,100	Notes Issued	£145,984,595
Other Securities	8,734,900		
Gold Coin and Bullion	126,234,595		
	£145,984,595		£145,984,595

BANKING DEPARTMENT

RESOURCES		LIABILITIES	
Government Securities	£47,312,032	Proprietors' Capital	£14,553,000
Other Securities	77,040,564	Rest	3,338,068
Notes	19,708,380	Public Deposits	11,772,876
Gold and Silver Coin	1,823,449	Other Deposits	116,161,716
		Seven Day and Other Bills	8,765
	£145,884,425		£145,884,425

For the explanation of the apparent paradox, we must look to three different sets of circumstances:

1. There are seasonal variations in the demand for money in England, but these variations are not comparable in magnitude to those occasioned by the crop-moving period in the United States and Canada. An elastic hand-to-hand circulating medium is therefore not so necessary in England.

2. A very large proportion of the business of England is transacted by means of bank checks. English bank deposits, as contrasted with bank-notes, are highly elastic. They are able to fluctuate freely with the needs of trade. During the fifty years preceding the Great War the supply of bank-credit in the form of deposits subject to check was more perfectly elastic in England than in any other country in the world.

3. In emergency, the operations of the bank act may be suspended, so as to permit of an increase in the uncovered note issue of the Bank of England. This occurred in several earlier financial crises as well as during the Great War. Because of the possibility of suspension, the bank, by issuing most of its notes virtually in gold certificates, accumulates in normal times a store of gold in its issue department which can be utilized as a reserve for yet further note issues in time of emergency. This explains the comment of Sir Robert Peel that the real merit of the act was to be found in the accumulation and preservation of a large stock of gold which could be made available by its suspension.

4. Now let us pass to the part of the bank return which is headed "banking department". That department, we repeat, is quite separate and distinct from the issue department. The strength of the bank is not determined by the size of its capital so much as by its peculiar position in the world's money market. The "rest" is a reserve fund corresponding to surplus and undivided profit in the statements of banks in the United States. "Public" deposits are those of the government, and "other" deposits comprise not only the accounts of private customers but also the accounts of other banks, for the Bank of England is a bankers' bank. Its cash reserves contain the greater part of the gold of England. Other banks keep a small supply of sovereigns and other coins on hand as till money, but most of their money is kept with the Bank of England and appears in the return under the term "other deposits". We should understand, therefore, that the really small amount of gold coin and bullion held in the banking and issue departments of the Bank of England is the foundation of the whole structure of English credit. More than that, this small store of treasure was before the Great War, and probably will be again, the world's central gold reserve. We may find it amazing that not only the hundreds of thousands of current domestic debts in England payable on demand in gold are backed up by such a tiny amount of actual cash, but that these same small hoards also constitute the means by which the balances arising out of international trade are in large measure paid.

The reader will now realize how great are the responsibilities of the Bank of England. The English economist Bagehot said: "On the wisdom of the directors of that one joint-stock company, it depends whether England shall be solvent or insolvent." We may go further and say that the smooth functioning of the great machinery of international commerce depends in no small measure upon the wisdom with which the Bank of England is managed.

The Bank of England is a private institution with public duties. It fulfills the most important functions, but it remains today as it always has been an institution fulfilling its responsibilities without acknowledging any formal duties or legal obligations in the matter. Its reserve, it is interesting to note, has increased, but not in proportion to the growth of the trade of England or of the world. In the 'seventies and 'eighties of the nineteenth century, it ranged from £12,000,000 to £15,000,000; in the 'nineties, it rose to over £20,000,000 and in 1912, as the return we have reprinted

indicates, it was £26,000,000. The real reserve of the Bank of England, the reader will observe, is equal to the amount of gold and Bank of England notes held in the *banking* department. Gold coins and bullion held in the issue department over and above the amount of notes in the hands of the banking department are offset, of course, by notes outstanding in the hands of the public. In the case of a sudden demand for gold, all the notes outstanding, except those already in the hands of the bank, might be presented for payment. But just in the measure that the bank holds its own notes, its gold reserve, thus free from prior claims upon it, is the basis upon which the enormous structure of deposit credit in England is based.

"All banks depend upon one, and all merchants depend on some banker"

As to the Bank of England's view of its responsibilities, Bagehot, writing in 1873 in his famous "Lombard Street", remarked: "All banks depend on the Bank of England, and all merchants depend on some banker. If a merchant have £10,000 at his banker's, and wants to pay it to someone in Germany, he will not be able to pay it unless his banker can pay him, and the banker will not be able to pay him if the Bank of England should be in difficulties and cannot produce his reserve. The directors of the Bank are therefore, in fact, if not in name, trustees for the public, to keep a banking reserve on their behalf; and it would naturally be expected either that they distinctly recognized this duty and engaged to perform it, or that their own self-interest was so strong in the matter that no engagement was needed. But, so far from there being a distinct undertaking on the part of the Bank directors to perform this duty, many of them would scarcely acknowledge it, and some altogether denied it."

These words are as true today as when they were written. The Bank of England does not admit responsibility, and yet it is responsible. Successive governments acknowledge that the subject is important, and pass on to less important matters.

How the Bank of England's reserve is affected, and how it matters to all

In view of the great importance of the subject, we must now see what it is that chiefly affects the bank's reserve of gold, and what the reserve matters to the ordinary man. Unfortunately, these things matter very much in the daily affairs of life; and while there are few newspaper readers who understand the money column, there may be large groups of unemployed, and business men bitterly suffering, because of things happening which are recorded in it — plainly for those who understand, obscurely for those who do not.

It is necessary first to show the part which gold plays in international trade and the foreign exchanges. Foreign transactions have much to do with the price of money. What do we mean by the "price" of money? How can money have a price? The answer to these questions is that the word here means something quite different from "price" as applied to goods. The price of a commodity means the amount of money for which it will exchange. The price of money means the rate of interest asked for the loan of it.

The way in which ordinary business is affected by the bank rate

When we speak of the "money market" we mean the places in which money may be borrowed. Very clearly, when money — *i.e.*, loan money — is in plentiful supply, the rate of interest is low, and money is said to be "cheap". When money is scarce, and loans are difficult to negotiate, the rate of interest advances, and money is said to be "dear".

Of course, it matters a great deal to the business man what the price of money is. If a builder, for example, has to pay 7 per cent for money instead of 5 per cent, it makes a very great difference indeed to his chance of a successful venture. If the price of money rises, we have an immediate check to business; and, conversely, when money is plentiful, business is stimulated. Good business, by creating a demand for loans, tends to raise the price of money, and *vice versa*.

When gold becomes necessary to balance international payments

We showed in a preceding chapter how goods are exchanged for goods in the same country by means of promises to pay gold, which we call "checks" — promises which are offset one against another by banks. This offsetting renders the passing of gold in business almost entirely unnecessary.

When we come to external commerce, the promises to pay gold take the form of bills of exchange, which are actually promises (or "accepted" *orders*) to pay gold at some future date. We do not pause here to explain the machinery of the bill of exchange in detail, for the reader will not be misled if he imagines the process to result in the same way as the exchange of checks, described in a preceding chapter. It will be apparent, however, that if two countries, say the United States and England, trade with each other, it is highly improbable that at any given time the goods sold by Americans to Englishmen will be exactly equal in value to those sold by Englishmen to Americans. Therefore, it may not be at any given moment possible to set off paper promises to pay in such manner as entirely to resolve the transactions between the two nations. Of course, in practice the offsetting takes place between more than two nations, but it simplifies what we have to explain to fix our minds upon two nations only.

Imagine, then, that at a given time the goods sold by the United States to England, and due to be paid for, are worth $25,000,000, while the goods sold by England to the United States, and due to be paid for, are worth $24,500,000. It will be seen that, so far as $24,500,000 is concerned, all that need be done is to offset promises to pay gold against each other, leaving a balance of $500,000. Under these circumstances, the $500,000 must be paid in actual gold shipped from England to the United States. It would thus become necessary to obtain gold from the Bank of England and to export it to New York. As a consequence, the reserve of gold at the Bank of England falls, and the English money market is affected.

Why the price of money is raised in London from time to time

How, then, does the Bank of England protect its gold reserve from such depletion? It has both to supply gold on demand and yet to prevent its reserve from falling to a dangerously low point. To give the answer in the simplest form, what the Bank of England does is to *raise the price of money in London*. The means by which it effects this is by raising what is called the bank rate, *i.e.*, the rate at which the Bank of England will discount first-class bills of exchange or lend money on good security for short periods. The official bank rate, because of the peculiar importance and power of the Bank of England which prescribes it, determines the market rate, or practical rate of discount, which runs a shade below it. Experience has shown again and again that the raising of the bank rate is effective in retaining gold in London or even in attracting additional supplies from other countries. The Bank of England has not infrequently thus to protect its gold reserve.

Thus, when in 1907 there was a financial panic in the United States, when business men were rushing to their banks for gold, and the banks in turn began to call on London for gold, the Bank of England raised its rate, and prevented too great a drain upon its resources.

So far we have avoided the difficulty that different countries have different coinage, but we must now consider this in detail, and see how foreign exchanges are in practice regulated.

It will be readily understood that as between the gold coins of two gold-standard countries the question is not what the coins are called, but what is the amount of pure gold in the coins. Considering this, what is called the "mint par of exchange" is arrived at. For example, what is the relation of the pure gold in the French pre-war coinage (napoleons) to the pure gold of the coins of the United States? This is easily calculated, and we find that a dollar has as much pure gold in it as rather more than five gold francs — the precise equivalent is 5.18 francs.

The causes of the rise and fall of the rates of exchange

Again, the mint par between the United States and England is 486.7 cents to the pound sterling. We hope we have made it clear that the mint par of exchange has sole relation to the amount of pure gold contained in the various coins. Obviously, as between a gold-standard country and a silver country, like China, there cannot be a mint par of exchange. Now let us suppose that as between two countries the claims for payment at a certain time are equal. That being so, exchange is at the theoretic par of exchange — *i.e.*, if the two countries were the United States and England the claims would be settled at the exchange rate of approximately the English sovereign, $4.87. But, of course, it rarely happens that there is such an equivalence of indebtedness between any two countries; and it will be seen that if on a certain date there is more to remit from the United States to England than from England to the United States, there will be a considerable demand in the United States for bills of exchange as a means of remittance to London. Consequently, the price of a bill of exchange would rise in New York, or, in other words, the rate of exchange would rise.

To express it in another way, a bill on London would be at a premium; an American importer desiring to remit would be willing to pay more than the mint par of exchange — *i.e., more than 486.7 cents per sovereign for it.* There is, however, a practical limit to the premium he would be willing to pay. That limit is fixed by the cost of buying, shipping and insuring gold, and that limit is known as "the gold point". A moment's thought will show that this gold point strictly limits the premium of exchange, and is the point at which gold is paid instead of a bill of exchange, or promise to pay gold.

The insignificance of the commerce in gold compared with the bulk of trade

Now we see how it is that gold comes to be shipped in settlement of debts between one country and another. In relation to the enormous bulk of international transactions which take place, the shipments of gold are trifling. In point of actual size, however, the shipments of gold are great. For example, in the year 1924 the commerce in goods and gold of the United States was as follows:

SHIPMENT OF GOODS AND GOLD: 1924

Imports of Goods	$3,609,963,000
Exports of Goods	4,497,649,000
Exports of Imported Goods	93,335,000
Total Trade in Goods	$8,200,947,000
Gold Imported	$319,721,000
Gold Exported	61,648,000

It will be seen that while in a single year our imports and exports of merchandise amounted in value to the enormous sum of $8,201,000,000, our inward and outward shipments of bullion and specie amounted to less than $400,000,000. It it plain, therefore, that the great bulk of the necessary payments were made by the transmission of bills of exchange, and that the shipment of gold played only a comparatively small part. Nevertheless, when transactions in gold are compared with the gold reserve at the Bank of England and other central banks we get a very different effect of proportion. In relation to the total volume of trade the commerce in gold is insignificant; *in relation to the bank reserves the commerce in gold is considerable and significant.* We see that it is large enough and frequent enough to have a very appreciable effect on the money market.

The daily table of foreign exchanges a thermometer of trade balances

We can understand, then, how important are the tables of foreign exchanges which appear in the money columns of the daily newspapers, and how closely they are watched. The movement upward or downward of rates of exchange with any particular country shows in which direction the balance of indebtedness is tending. For example, here are the rates of exchange as they were given in the daily newspapers of January 31, 1924:

FOREIGN EXCHANGE

Sterling — Par $4.86\frac{5}{8}$.	
Demand	$4.26\frac{5}{8}$
Cables	$4.26\frac{7}{8}$
Sixty-day bills	$4.24\frac{5}{8}$
Francs — Par 19.3 cents.	
Demand	$4.64\frac{1}{2}$
Cables	4.65
Guilders — Par 40.2 cents.	
Demand	37.22
Cables	37.27
Lire — Par 19.3 cents.	
Demand	$4.34\frac{1}{2}$
Cables	4.35
Marks — Par 23.8 cents.	
Demand	.0000000000002
Cables	.0000000000002
Norwegian Kronen — Par 26.8 cents.	
Demand	13.63
Cables	13.65
Argentine Pesos — Par 42.45 cents.	
Demand	32.71
Cables	32.76

Expressing the meaning of the table broadly, it is as follows: it shows the price which had to be paid at the time in New York for a demand bill payable at sight upon the leading money market in each of the different countries. The "cables" which are quoted in the table, are virtually demand drafts sent by cable instead of by mail. The price of cables, it will be noted, is generally a little higher than the price of ordinary demand drafts. This is not so much because of the expense of cabling — a relatively small matter in a large transaction — as because it takes some time for the ordinary draft sent by mail to reach a foreign country, and therefore a slight allowance for interest is made in the price. The price of 60-day bills on London, it will be further observed, is always lower than the price for ordinary demand bills. This difference also is to be attributed to discount or interest, the controlling interest rate in this case being the rate prevailing in the London money market. In general, a 60-day bill on London is worth in New York approximately as much as a demand bill on London with deduction for interest or discount for two months at the prevailing London rate.

The reader will note that the rates of foreign exchange quoted in the table are in every instance not merely below par but even far below what would ordinarily be the gold import point. The explanation is, of course, that in 1924 most of the countries of the world, not including the United States, were utilizing irredeemable paper currency as money. To pay the extraordinary expenses created by the Great War and of the period of reconstruction which followed, the governments of these countries induced their banks to issue notes in quantities so large that their redemption in gold was for the time being — and in some countries permanently — impossible. Before the war the franc was an actually enforcible right to demand a certain amount of specie in Paris, just as the mark was a real title to gold in Berlin. But with the changes brought about by the war, the franc and mark and other continental European currencies became simply promises to pay gold at some indefinite time in the future, — promises which it is wholly unlikely will ever be completely fulfilled.

Foreign exchange rates determined by supply and demand

Foreign exchange rates, like other prices, are determined by supply and demand. Exports create a supply of foreign exchange. Imports in a similar way create a demand for it. The American cotton exporter collects from his English customer by means of a bill of exchange drawn upon London. When such a bill is collected or sold in England and the proceeds put in a bank there, it becomes a credit upon which the United States can draw in payment for imports.

It must be remembered, however, that in exports and imports we include many other things than the commodities which figure in the ordinary statistics of international trade. *All things for which we have to pay other countries are imports. All things for which they have to pay us are exports.* Thus among the more important exports of the United States are commodities, American securities (bonds, stocks, etc.) and claims for the payment of interest and dividends on foreign securities owned in the United States. By such means, the United States builds up bankers' credits in foreign countries.

Imports in turn include commodities, foreign securities, claims on the part of foreign investors to interest and dividends payable by American governments and by business corporations, expenses incurred by American tourists abroad, etc. Ocean steamship freights, payments for marine insurance and the earnings of the banks engaged in the foreign exchange business also enter into the true balance of trade on the one side or the other.

The significance of the larger meaning of exports and imports should now be clear. Whether or not a transaction involves the physical removal of a commodity from one country to another is immaterial. The wealthy American who pays a high price for an old Italian painting is of course an importer. But so are the other Americans who visit the picture galleries of Italy to see the works of the old masters. So far as the effect on foreign exchange is concerned, Italy may be said to export her climate and her art galleries quite as truly as she exports her olive oil and her silk. Some of the manifold and complex factors that enter into the true balance of trade are revealed by the accompanying estimate of the international balance of the United States for the year 1924. This estimate was made by Mr. Herbert Hoover, Secretary of Commerce, and it was published in a Department Bulletin in April, 1925. Speaking as it does for a year of financial confusion and turmoil, the statement includes a number of unusual items, but it is all the more instructive on that account.

Gold shipments figure in this statement as exports and imports. In normal times when the currencies of the great nations of the world are based on a gold standard, it is better to take separate account of gold shipments, for they are really *the means by which the international balances are paid.* This will be clear if we reflect for a moment upon the operations of the gold points, as described above. If exports largely exceed imports, the supply of foreign exchange will be relatively large as compared with the demand for it. As soon as the price of exchange falls to the gold import point, however, gold will begin to flow in from other countries. The banks whose balances abroad have been increased by exports find it more profitable to exchange some of those balances for gold and to pay the expense of importing the gold rather than to sell their drafts or bills of exchange drawn against

BALANCE OF INTERNATIONAL PAYMENTS OF THE UNITED STATES: 1924

(*In millions of dollars*)

(Estimate made by Herbert Hoover, Secretary of Commerce)

Items	Credit	Debit	Balance
Merchandise	4,621	3,651	+ 970
Interest and dividends	614	150	+ 464
Ocean freights	76	68	+ 8
Government payments		5	− 5
Services to tourists	100	600	− 500
Charitable and missionary expenditures		55	− 55
Immigrants' remittances		300	− 300
Foreign loans, exclusive of refunding		795	− 795
Sale and purchase of outstanding securities	319	114	+ 205
Foreign bonds paid off	45		+ 45
Principle of interallied debt	23		+ 23
United States paper currency		50	− 50
Gold and silver	172	394	− 222
Total	5,970	6,182	− 212
Add increase in foreigners' bank deposits			+ 216
			+ 4

those balances at the low price prevailing in the market. This is the simple but extremely effective mechanism by which an excess of exports or imports, that is, a favorable balance of trade, necessarily leads to gold movements. Conversely, of course, if any country has for some time been importing more than it has been exporting, the demand in its markets for foreign exchange will be relatively large as compared with the supply. Under such conditions, the rate is sure to rise to the gold export point and gold will flow out in settlement of the country's adverse balance of trade.

To what conclusion the Ricardian principle of gold movements leads

This brings us to the consideration of one of the most important doctrines of economic science: the so-called "Ricardian principle" of gold movements. As a matter of fact the doctrine was well known before the days of the distinguished English economist, David Ricardo, but it was expounded by him in masterly fashion. We shall state first the conclusion to which the doctrine leads and then explain the reasoning upon which it is based. The conclusion is that no country can long maintain a favorable balance of trade. It is equally true of course that no country can for many successive years have an unfavorable trade balance. It will be understood that we are speaking of the *true trade balance* and not merely of the visible balance of commodity exports and imports.

And the reasoning upon which the conclusion is based

The reasoning upon which this conclusion is based is simple: A country whose exports exceed its imports drains gold from other countries. Its monetary circulation and its bank reserves increase. Money and bank-credit become relatively plentiful as compared with other things. Because they are more plentiful, their value decreases; that is, the general level of prices increases. The new and higher price level attracts imports from other countries and at the same time makes it more difficult to export successfully in competition with the cheaper goods of other countries. Through the operation of the increased supplies of gold, therefore, *the current of trade is reversed.* Imports come to exceed exports; gold is drained away by other countries who claim it in the payment of trade balances, now favorable to them; the price level moves downward again, and the cycle repeats itself. This doctrine, it should be understood, does not rest merely upon the basis of logic, of "pure reasoning". Like every other established scientific principle, it is accepted by competent experts because it successfully and satisfactorily explains the observed facts. Statistics of foreign trade and of gold movements square with the Ricardian doctrine. In fact, it is one of the most firmly established as well as one of the most important of economic doctrines.

We are now in a position to return to the Bank of England and to look into the mechanism by which the raising of its official discount rate safeguards its gold reserves. There is no magic in the official discount rate. In fact, it is hardly more than an official statement, a guarantee, that the bank stands ready to advance funds on high grade bills of exchange at the stated rate. As a matter of fact, most of the business of the London money market will be done at a distinctly lower rate. But the Bank of England expects that when it raises its rate, the rates prevailing in the general market will follow suit.

If they do not do so, it resorts to means of putting pressure on the market. For example, it may sell large blocks of its holdings of securities, thus absorbing the market's surplus funds and securing — through the collection of the checks paid for the securities thus sold — a transfer of funds from other banks in London to itself. Induced or forced to replenish their reserves — that is, their own credits at the Bank of England — the other banks turn to it for help. Then the Bank of England is in a position to name its conditions and to enforce what it holds to be the proper market rate of discount,

Effects of advance of discount rates by the Bank of England

When discount rates in the London money market have advanced as the result of the bank's initiative, what effects do they have? It is not true, as some have supposed, that high discount rates in themselves attract gold to the centers where they prevail. That is in truth their ultimate effect, but the mechanism by which they operate is roundabout and indirect. They attract gold because they *diminish and repel borrowing*. Some money, of course, will be borrowed at the higher rates. But other borrowers will prefer to wait and yet others will find that the high rates preclude profits from the enterprises they had in mind. The reduction of domestic borrowings in the London money market will in itself lessen the load upon the banks' reserves but the effect of the high discount rates is much more far-reaching than that. London discount rates, although extremely variable, are in general the lowest that obtain in any of the great money markets of the world. For this reason, London banks and money lenders normally hold large quantities of bills drawn to finance the trade of other countries in all parts of the world. Bills of exchange, like other commodities flow to the markets where they command the highest prices. To say that the discount rate is low is merely another way of saying that the price of bills of exchange is high. Thus, if the prevailing discount rate is 6 per cent per annum, the price of a 90-day bill of exchange for $10,000 is $9,850, while, if the prevailing discount rate is only 4 per cent, the price of the same bill is $9,900. Money lenders and dealers in bills of exchange sell them in the best markets. London, as we have said, normally holds many of them. But an increase in the London discount rate is equivalent to a decrease in the price paid for such bills in London. The flow of bills from other countries will be reduced or stopped, some foreign bills held in London may be resold to their home markets, and under extraordinary conditions, English bills may even be exported.

Important secondary reserve of London market in its holdings of foreign bills

The fact is that in its holdings of foreign bills, the London market has a secondary reserve of very great significance. The commercial paper which constitutes this reserve is a commodity the price of which varies exactly but inversely with the rate of discount. Slight changes suffice to turn it from an import to an export. It is thus an automatic mechanism by which England's trade balance is in normal times kept in a state of delicate equilibrium. When an adverse movement of the foreign exchanges threatens a drain of gold, the Bank of England, by raising its discount rate, avoids losses of gold by substituting for it a retarded inflow and an accelerated outflow of commercial paper and, on occasion, of investment securities. If, for example, the New York money market is demanding gold from London, London is normally able to transfer or pass on the demand to other countries by virtually saying to them: "We have changed our prices so that it will not be profitable for you to continue sending us bills of exchange and securities. In fact, you may find it profitable to take some of these things off our hands. Pay us, if you will, by sending New York the gold it is demanding." Thus the London money market in normal times should not be thought of as a gigantic financial center in which gold and investments are concentrated in enormous quantities, but rather as a sensitive intermediary or buffer through which the strains and stresses created by changes in the world's currents of international trade are transmitted and, in part, softened and absorbed.

London's international money market position cause and effect of low rates

It is a curious paradox that the London money market has been able to gain and hold this unique position largely because its discount rates are normally exceedingly low. For its discount rates are low partly because the banking business can be conducted in London economically. An enormous edifice of credit can be safely

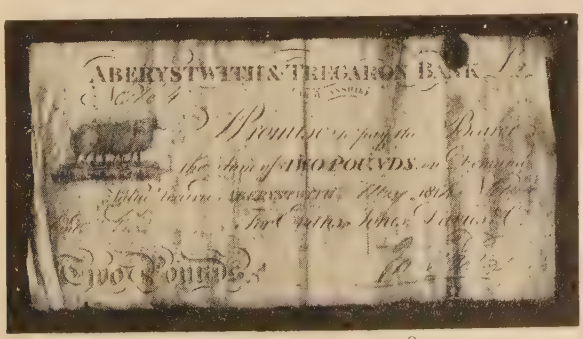
erected there on a relatively small gold foundation. London's low discount rate is thus seen to be at once the cause and effect of London's position in the international money market, and London's position in the international money market in a similar way is the cause and effect of her low discount rates.

Changes in relative importance of New York and London due to war

Notable among the many financial changes resulting from the Great War were New York's relative gain and London's relative decline as an international financial center. The positions of England and the United States were for the time being, at least, completely reversed. The United States suddenly became the world's greatest creditor nation, while England found itself, strangely enough, in the position of a debtor. The United States, thanks to the elasticity of the federal reserve system, was able to maintain the gold standard unimpaired throughout the war and the years of financial turmoil which followed. Moreover, during the early years of the war before the United States was a participant, American trade grew at the expense of the trade of the belligerent nations. Bills drawn upon New York rather than upon London came to be used in many parts of the world — in Latin America, for example — in financing a considerable portion of international trade. The demand for bills on New York as a means of paying European indebtedness also increased the prestige of the dollar at the expense of the pound sterling. With the general collapse of European currencies the stability of the dollar gave a further advantage to bills on New York.

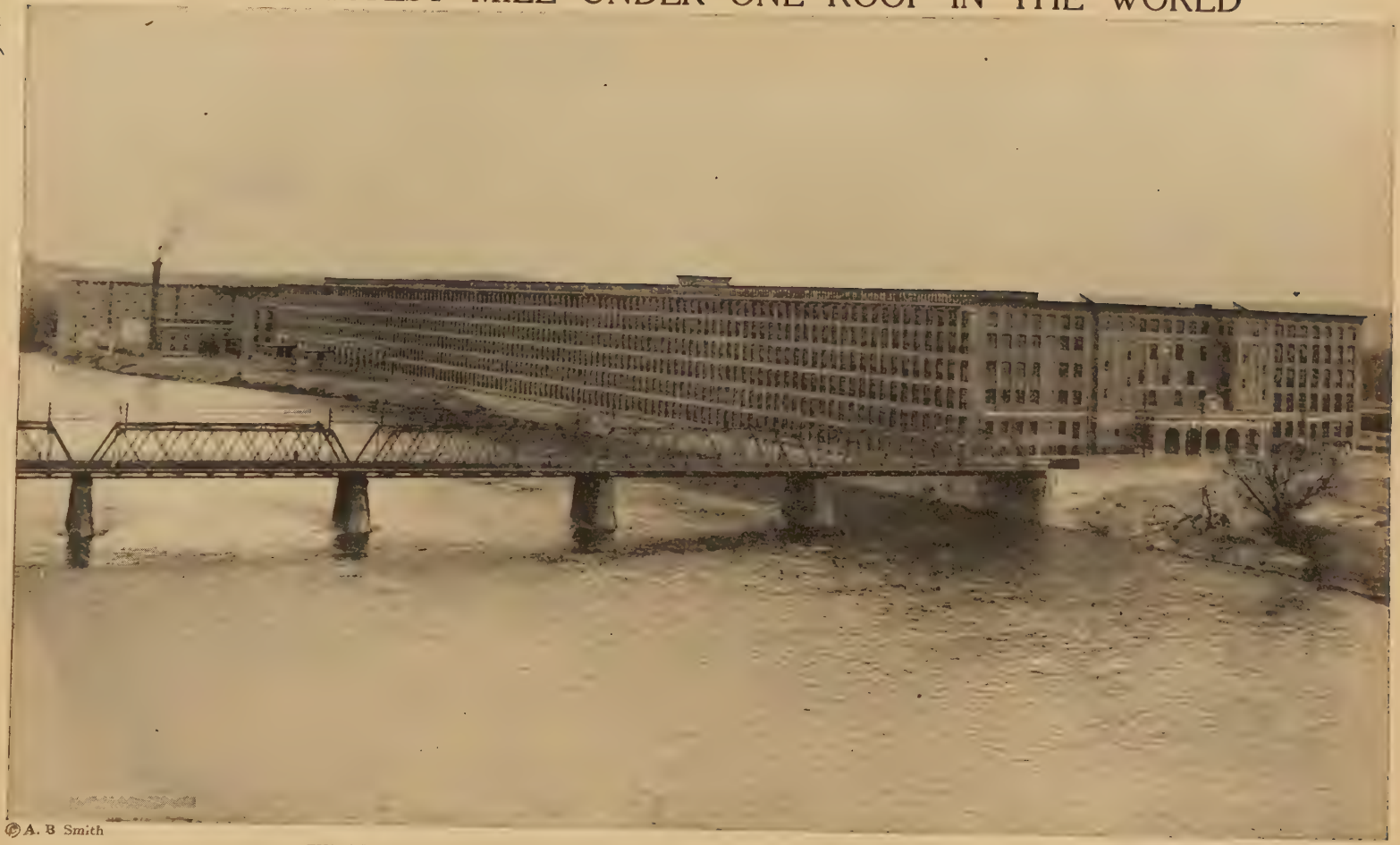
Why London will probably never cease to be the world's clearing-house

Some of these changes are likely to be permanent. The New York money market, with the vast wealth of the United States and the largest gold reserves in the world behind it, was certain, some even thought, permanently to displace the London market as the world's central foreign exchange clearing-house. Now there is no question but that in the future the international importance of the New York money market will be greater than it has been in the past, and that many international purchases which were formerly paid for in sterling will in the future be paid for in dollars, but these facts do not imply that London will cease to be the world's clearing-house. London's position is founded not so much upon the magnitude of English capital, of English trade, or of English gold reserves, as upon the highly organized and perfected machinery of the London money market, upon the elasticity rather than the sheer bulk of English banking reserves, upon the varied character and world-wide distribution of English trade, and upon England's geographical position, bringing London close to the other financial centers of Europe.



A WELSH BANKNOTE OF 1814

THE LARGEST MILL UNDER ONE ROOF IN THE WORLD



©A. B Smith

THE WOOD WORSTED MILL OF THE AMERICAN WOOLEN COMPANY AT LAWRENCE, MASS.

KEEPING MANKIND WARM

The Greatest Manufacture from Animal Products — the Woolen and Worsted Industries

HOW WOOL IS USED FOR MAN'S PROTECTION

THE changing of wool into clothing, apart from its use when attached to the skin of the sheep, must have been the oldest industrial process for protecting men from cold or wet. There are allusions to it in all ancient literatures; and we know that, quite early, men had acquired considerable skill in the methods of making wool into apparel. But though the business has been carried on for uncounted thousands of years, users of wool are not quite agreed upon a definition of wool itself — the basis of their manufacture. The difficulty is to distinguish between wool and hair. No one can tell where one ends and the other begins. Really, they begin and end on the same sheep, merging imperceptibly into each other. Wool is soft, curly, moist with a special oiliness, and covered with jagged scales; whereas hair, in these respects, is but a far-off imitation, passing into positive unlikeness. It is the serrated or jagged surface of the wool-fiber that gives it its peculiarity and its power of becoming interlocked and matted, or felted, and so serving as a warm protection in the form of clothing.

Wool is, broadly, either short and curly, or long and wavy rather than curly, and the distinction has led to a well-marked division in the manufacture, though that division is being narrowed constantly as time goes on. The short wool has been used for the making of woolen, and the long wool for the making of worsteds; but increasingly, under modern machine processes, the two kinds of wool are partly interchangeable for the making of the two different kinds of cloth — matted or threaded.

The sheep, the source of the wool, is one of the most widely distributed of animals, spreading over all the continents, and dividing into innumerable varieties. The best known breeds are the Merino which came from Spain, and the Leicester, Lincoln, Cotswold and others that originated in England. These, spreading from their original homes and mingling with each other or with other stocks, have built up almost all the important flocks on the earth. The wool of the Merino sheep is fine and soft, while that of the Leicesters and Lincolns is longer and coarser, and these varieties have been of great value in cross-breeding. Merino sheep were imported early into the United States and were the basis of most of the present flocks. It is to England, however, that we must look for the story of the rise of modern woolen manufacture.

There was a time, well within the range of recorded history, when England was a notable wool-exporting country, and the manufacture of woolen goods was chiefly carried on elsewhere. For hundreds of years the Flemings, in what is now northern Belgium, with Bruges and Ghent as their chief centers, were the masters of the secrets of the manufacture; and not once, but over and over again, covering a space of three centuries, parties of them were invited to England to establish their craft there. They arrived at intervals, a succession of minor immigrations, and, intermixed with Walloons from the more southern parts of Belgium, began the cloth trade of Yorkshire and the West of England and more particularly that of Norfolk.

For several generations Norwich was the chief English center of the woolen manufacture, and it only lost its preëminence by clinging to old-fashioned ways too long, and failing to adapt itself to new and revolutionary methods when the age of machinery arrived. The very name "worsted", which applies to something like one-half of the trade, is derived from a Norfolk village in which a band of skilful Fleming weavers settled.

The turning-point in the evolution of the woolen manufacture came when Dr. Edmund Cartwright, a Leicestershire clergyman, showed the world how to comb wool

SORTING MOHAIR FOR MAKING ALPACA

by machinery instead of by hand. His invention, as perfected by later inventors, had the same effect on the output of woolen goods as Whitney's invention of the cotton-gin had on the cotton trade. It was impossible for a great manufacture to be carried on adequately for all the world when the material had to be handled laboriously by manual labor, as was the case in the days of hand-combing; but a whole series of events, happening more or less simultaneously, gave an enormous impetus to the woolen industry. Sir Joseph Banks set himself, with the energy of a scientific enthusiast, to spread the Merino breed throughout the world, and particularly in England and Australia, at a time when the development of machinery made an urgent demand for the wool. The result was seen in a growing supply, as the power to use the wool rapidly expanded.

The coming of Cartwright into the world of wool-workers is one of the romances of industry. A Yorkshire man, educated at Oxford, he became a clergyman, addicted to minor poetry. With a parish first in Derbyshire and then in Leicestershire, he was apparently one of the most unlikely men for such an enterprise as mechanical invention. In 1784 he went to Matlock, a place that was then much agitated by the disquieting inventions of Arkwright, who recently had been driven, with his new-fangled machines, from Lancashire into Derbyshire. At the dinner-table in the inn the Rev. Edmund Cartwright heard the argument that Arkwright's cotton-spinning machinery in the end must be an evil, for it would make more yarn than the weavers could use, and the outcome would be that the yarn would be sold abroad, and then would come back as manufactured goods to compete with English manufactures.

Cartwright met this argument with the suggestion that what was needed was the invention of weaving machinery, so that the weaving in England might keep pace with the spinning of the yarn — a theoretical view that was ridiculed by the practical men present, who assured him that weaving by machinery was forever impossible.

Cartwright was so convinced that he was right that he went home and set himself the task of inventing a power-loom. This he patented, and manufactured for himself, amidst public obloquy, and with financial loss. Then he undertook, as his second task in invention, to make a wool-combing machine — the first of its kind in the world. His machine was first patented in April, 1790, and finally in May, 1792. It was named "Big Ben", and was worked by a horse turning a gin. It did not prove successful with the finer qualities of wool, but it established the principle on which trade pirates could, and did,

make successful machines, though many years passed before combing by machinery was as good as combing by hand. Cartwright eventually received a government grant of £10,000 for his invention of the power-loom, and died at the age of eighty, after declaring spiritedly, in the last year of his life:

> With mind unwearied still will I engage,
> In spite of failing vigor and of age,
> Nor quit the conflict till I quit the stage.

out in 1846, and, as improved by Schlumberger, it became a practical success.

The suppression of the hand-combers by machinery was one of the tragedies of invention, from the point of view of the workers. Long and steadily did these poor fellows fight against the inevitable, in the manner pictured in Charlotte Brontë's "Shirley". Now the machine triumphs all along the line, whether in combing, or spinning, or weaving.

JOSUÉ HEILMANN'S INSPIRATION — FROM THE PAINTING BY A. ELMORE, R.A.

Other inventors of wool-combing machines were James Noble (patent dated 1805), James Collier (1814), John Platt (1827), and George Edmund Donisthorpe (1843). The inventions and improvements by S. C. Lister (afterwards 1st Baron Masham) and Isaac Holden bring us to within touch of the present day. A contemporary rival of Donisthorpe and Lister, and, later, Lister and Holden, was Josué Heilmann, an ingenious Alsatian, who, according to tradition, received his inspiration while watching his daughters combing out their hair. His patent was taken

The processes by which wool is prepared for the woolen and worsted types of fabrication are partly common to both, and then diverge. The first step common to both is the sorting or stapling of the wool. The fleece of a single sheep contains many different qualities of wool; and the sorter, as he goes over the fleece, shears in hand, clips the different qualities, and throws them into an array of baskets varying from five or six in number to thirteen or fourteen. The wool differs not only according to the breed of the sheep, and the part of the body from which each lock is

A FLOCK OF SHEEP IN A COUNTRY WITH NEARLY FIFTY MILLION SHEEP

A SCENE FROM THE RIVERINA DISTRICT OF NEW SOUTH WALES, A STATE WITH NEARLY FIFTY MILLION SHEEP, OR HALF THE TOTAL FLOCKS OF AUSTRALIA

SUPPLIES FOR THE WORLD'S OLDEST INDUSTRY FROM THE WORLD'S OLDEST LAND

PREPARING WOOL FOR THE CARGO BOAT, ON THE BANKS OF THE NILE, WITHIN SIGHT OF CAIRO. BY FREDERICK GOODALL, R.A.

taken, but also according to the age of the animal. The finest wool is found on each side of the neck, on the shoulders, the ribs and the back; good wool on the thighs, haunches, and tail; and inferior in other parts. These qualities are given special names as, for example, picklock for the choicest wool; prime, choice, super and other trade names used by the sorters to designate the different grades.

The sorted wool has now to be cleaned. It is in a varying state of dirtiness, and always saturated naturally with a compound called yolk, which exudes from the sheep's skin, and contains potash salts that are a valuable manure. The careful farmer will wash out a good deal of this impurity, and appropriate its value for his own use. One of the great difficulties, particularly in Argentine wools, is the presence in the fleece of numberless vegetable burrs that can neither be removed by the sorter nor in the beating and washing processes which follow. The wool, having been beaten, is washed or scoured through a series of tanks till it emerges clean and white.

The aim in scouring wool is to prevent damage being done to the fiber while securing perfect cleanliness. It is easy to make the wool harsh in this process by either too great heat or too strong soap. The washing is now done almost entirely by machinery. Wool opens out naturally in water; and the latest tendency is to scour the wool with its own potash salts, through three to five "bowls", the last being for rinsing. It is then passed through squeezing rollers.

After this cleansing process, the wool is dried, slowly and carefully, by various types of machines, which generally utilize a hot-air blast. The dried wool then has to be opened out and loosened, or teased, and this is done in a machine called a "willey" or "willow", which separates the fibers through the action of a toothed cylinder, revolving against a slower action of "workers", that just clear the teeth and contest for possession of the wool.

DIPPING SHEEP PREVIOUS TO THEIR SHEARING AT AN AUSTRALIAN SHEEP FARM

A point in the process has now been reached when an attempt is generally made to free the wool of vegetable matter. This is effected by one of two methods — either the burrs are removed mechanically by a machine working on much the same principle as the willow, and knocking off the burrs, or by the use of a carbonizing agent that will destroy the vegetable burr without injuring the animal matter of the wool.

THE SORTING OF THE WOOL

GRADING FLEECES

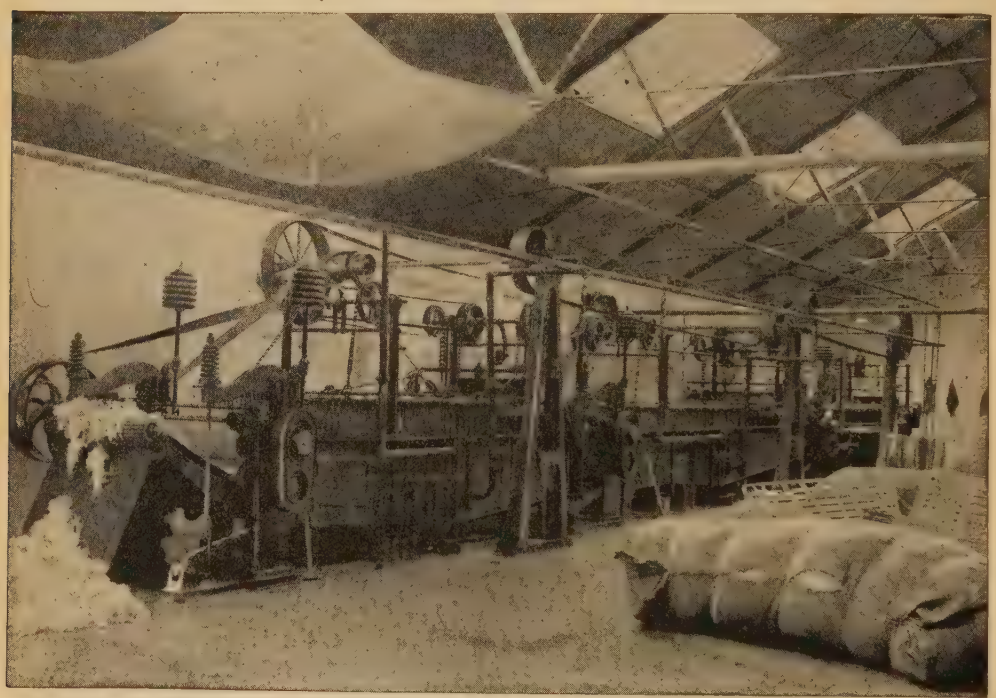
INSPECTING AND BLENDING

From copyrighted photographs loaned by the American Woolen Company

These methods of utilizing wool have added greatly to the amount of raw material available, as formerly the burr-encumbered South American wool could only be used for quite inferior cloths.

The washing and drying of the wool has removed its natural oiliness and left it difficult to work. It is therefore now oiled, whether it is about to be made into woolen or worsted yarns; and henceforward there are considerable differences in the modes of its treatment, according as it is to be carded and milled or felted as woolen cloth, or to be gilled and combed before being spun into yarn for worsted goods. In either case the operations are so increasingly complex, as the making of cloth becomes more elaborate and complicated, that only the barest outline of the various processes can be indicated here.

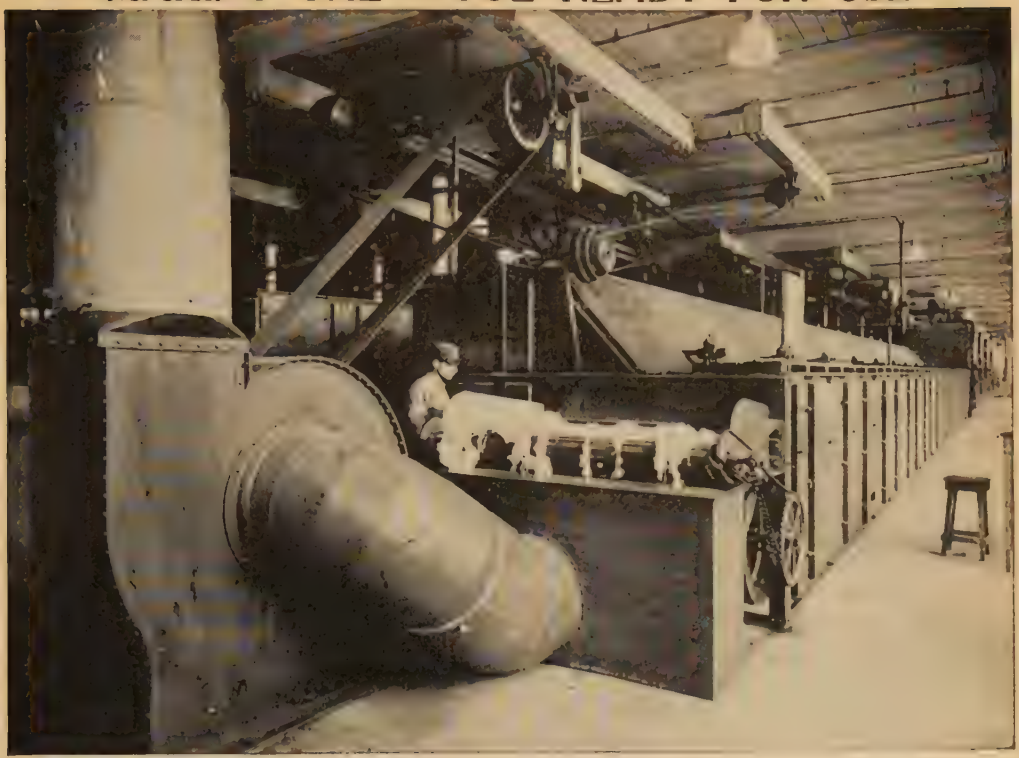
Take first the production of woolen cloth, although it is more and more difficult to find such a thing in purity. Cloth, by preference, is made from short wools that will form the more readily into a fluffy yarn, which felts or mats naturally, and the object of the process is to cause the fibers to be thoroughly interlaced and mixed. But first with the oiling comes the blending; and into the blending operation can go not only all kinds of wool, but all kinds of other material: ground-up garments — known as "mungo"; blankets, stockings, rags — known after treatment as "shoddy"; flocks or the fluffy fibers thrown off during manufacture; wool waste, cotton, silk waste and anything of a similar character. These materials are all passed through the willey, or "fearnaught", as it is sometimes called, a powerful machine with rotating teeth which tears all of them to pieces. The torn material is laid in layers one over the other and oiled as each layer is added till there is a "blend stock" of different stuffs. This is passed through the willey and is then ready for carding.



THE WOOL, WASHED WHITE FROM ITS GREASE AND IMPURITIES BY POTASH SOAP, IS HERE SEEN DELIVERED CLEAN BY THE LAST OF THREE SCOURING-TANKS

Carding of woolen yarn is usually done in a series of three machines which are much alike in general character. In America these machines are called respectively the "first breaker", the "second breaker" and the "third breaker" or "finisher".

MAKING THE WOOL READY FOR USE



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WOOL SCOURING-DRYING MACHINE

THE OPENING OUT AND SEPARATION OF THE LOCKS OF WOOL BY THE "WILLEY"

In England they are known as the "scribbler", "intermediate card", and "condenser card". Each breaker consists of a large cylinder against which several small cylinders called "workers and strippers" revolve. All of these cylinders are covered with thousands of small teeth, becoming finer in each succeeding breaker. The object of these teeth is to open up and thoroughly mix the wool, and it flows from the last breaker in a wide sheet. It is next passed through a "condenser", which divides the sheet into strips and rolls them into lightly twisted "rovings", which are wound upon large bobbins and go directly to the spinning frames.

Woolen yarns are most usually spun on the "mule", so called. This machine consists of a heavy carriage moving backward and forward on a track and carrying a large number of spindles. As the carriage moves outward the rovings are attenuated and at the same time they are twisted by the spindles. On the backward travel of the carriage the yarn is wound upon spools or bobbins that are carried on the body of the spindles. Mule-spinning produces a softer yarn than the methods of spinning that are used in producing worsteds, though some soft worsted yarns are spun on mules. If the yarn is to be colored or dyed, it must be wound into skeins or hanks on "swifts". If the yarn is to be woven as it is, it goes to the loom upon the bobbins as they come from the mule. Since the process of weaving is much the same in both woolen and worsteds a description of this process will be deferred until after a brief description of the preparation.

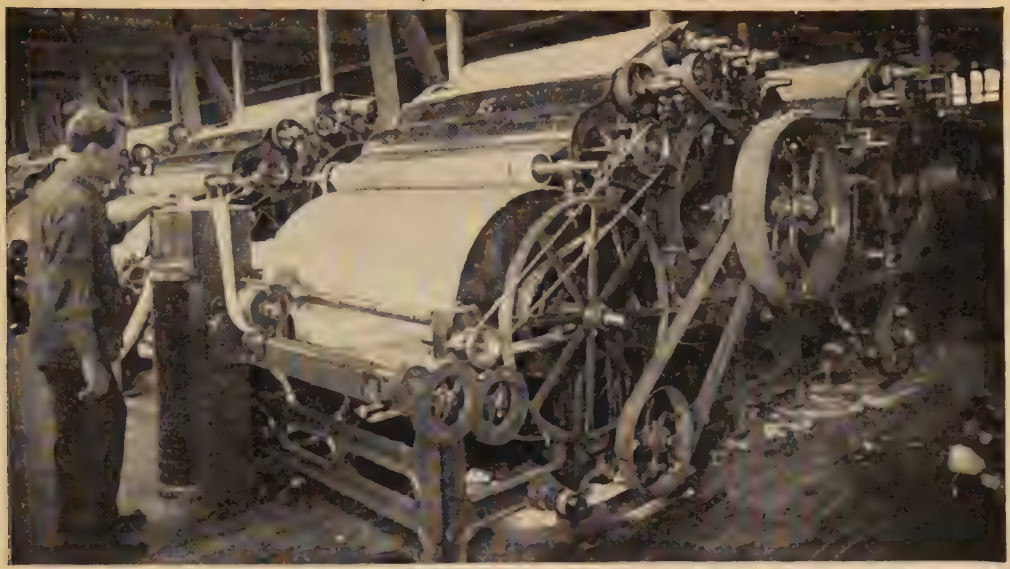
The preparation of worsted yarn differs from that of woolen yarn in that the wool fibers must be combed until they are parallel and not mixed promiscuously. The process is therefore somewhat longer than that for preparing woolen yarns. The carding of worsted yarn is performed in carding machines very much like those used in the preparation of woolen yarn. They differ, however, in being slower of movement and in the special care that must be taken in their adjustment and operation to prevent the breaking of the long-fibered material that is used for worsted yarn. When the carding process is completed worsted wool is condensed into thick untwisted ropes or "slivers".

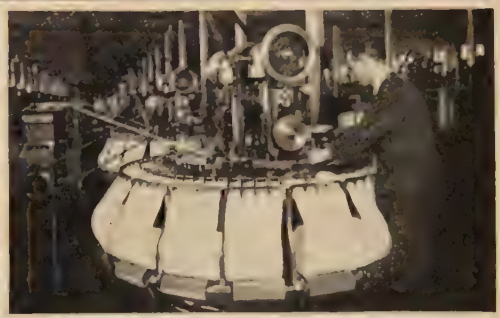
These slivers are now "backwashed" to remove any oil that may have been taken up in the process of carding. This process consists simply of several successive bowls and wringers in which the sliver is successfully washed in soapy water and passed through the wringers, the finishing operation being the thorough drying of the sliver either by passing it over a hot cylinder or by exposing it to a blast of air from a fan.

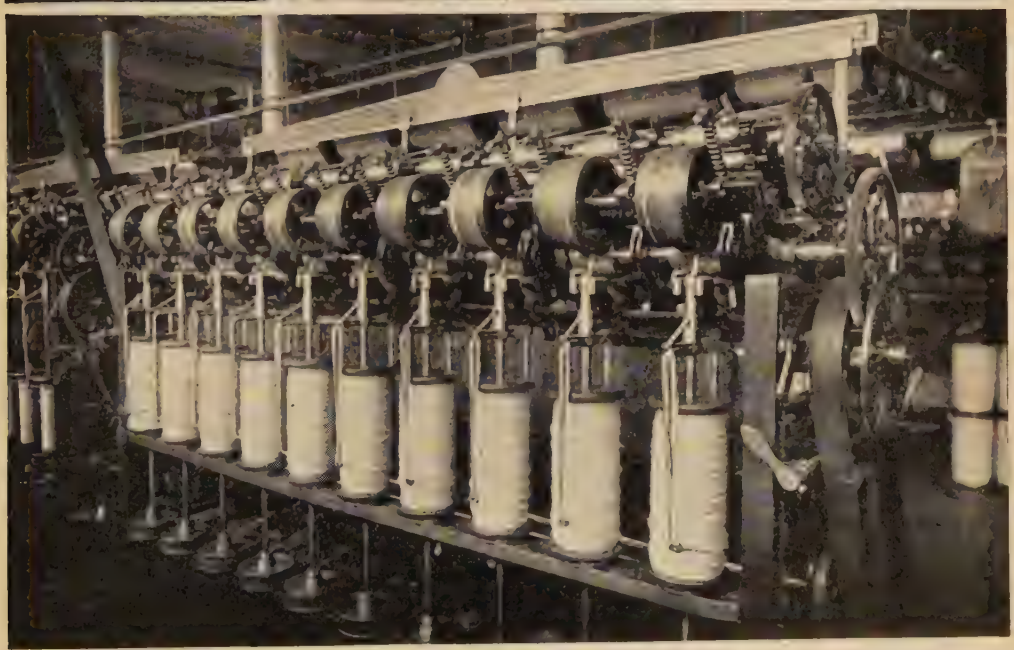
The slivers are now passed through a set of "preparers", the object of which machines is to unite a number of slivers and to draw them through a set of bars having teeth which still further straighten out the fibers and lay them parallel to each other. The wool comes from the preparers in soft strands. Four of these strands are taken to a balling machine and made into a large ready ball for the combing process.

Combing is one of the most interesting of the processes in worsted manufacture and was one of the most difficult to develop. When the wool comes from the preparers the fibers are fairly parallel, but short curly fibers are mixed with the long ones. The object of combing is to take out these short curly fibers and to comb the long straight wool into a parallel state known as "tops". There are several methods in use for accomplishing this result and one of the best-known machines is the Noble comb. This machine consists essentially of a flat ring about 5 feet in diameter which rotates around a vertical axis carrying on its upper surface several rows of upright pointed teeth. Two similar rings about 20 inches in diameter are located inside of the large ring and at opposite sides of the latter their outside surfaces almost touching the inside surfaces of the large ring. These small rings also carry rows of upright pointed teeth. All of the rings rotate in the same direction. Eighteen of the balls that come from the balling machine are placed in creels around the outside of the large ring and travel with it. As each ball approaches the point where the large ring is tangent to one of the small rings the sliver

CARDING, GILLING, COMBING AND DRAWING







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1. Worsted carding. 2. Gilling after carding. 3. Combing on Noble combs. 4. Drawing the tops.

of which it is composed is fed horizontally across the upright teeth and pressed down upon them by a dabbing brush. As the teeth of the two wheels begin to separate because of their rotative motion, the long fibers are left projecting from the outer side of the small rings and the inner side of the large rings. These projecting ends are picked up by a stationary vertical roller and, guided all in the same direction, they flow like a ribbon into tubes which condense them into a sliver called the "top". The short fibers which are not long enough to reach the collecting roller are stripped from the rings and passed down a funnel and out of the worsted industry. This material is known as "noils" and it is used in the manufacture of woolen goods where short fibers are permissible.

After the combing process the wool is passed through "gill-boxes" so called, which complete the process of laying the fibers parallel. These gill-boxes are similar in construction to the preparers that have already been referred to, preparing and gilling being practically the same process, the difference in name referring to whether the process precedes combing or comes after it. The top is now drawn between revolving rollers until it is attenuated sufficiently to spin. It comes from the last set of drawing rollers slightly twisted and is known as "roving". The roving is wound up on large bobbins and is carried to the spinning room.

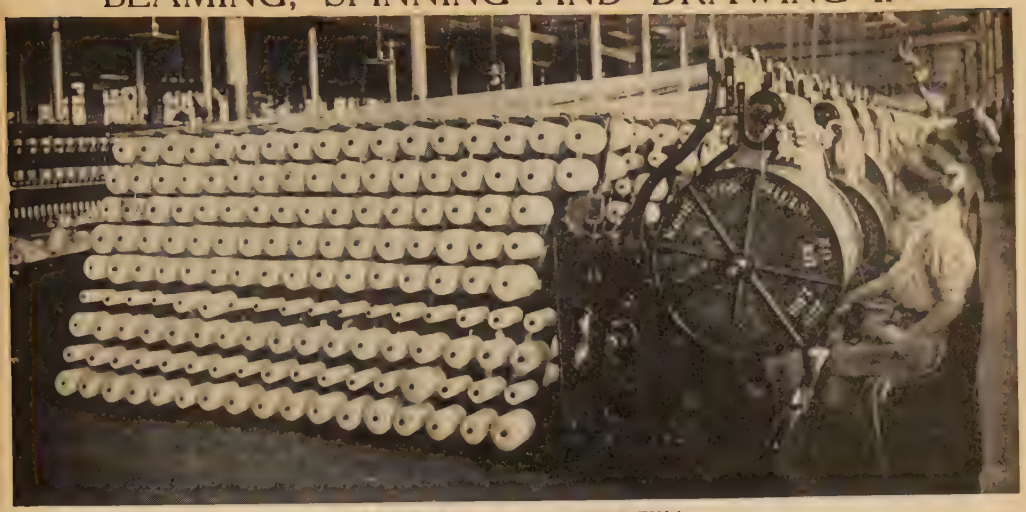
Soft worsted yarn is spun on a mule very similar to that used in spinning woolen yarn, but the greater part of worsted yarn is spun by the "flyer", "cap", or "ring" method which are based on the principle of the old Arkwright machine. These methods are difficult to describe and it will suffice to note that the most important difference between them and mule-spinning is the much greater friction in the process resulting in a greater tension in the yarn and hence producing a harder, smoother and stronger product. The long fiber used in worsted manufacture naturally aids in obtaining these characteristics in the yarn.

Wool may be dyed in one of three stages of manufacture. Sometimes it is dyed in the top before the final gilling or it may be dyed just after spinning. It may also be dyed after weaving. If it is necessary to dye the yarn it must be run off the bobbins into skeins or hanks and after dyeing wound back on the bobbins. Before dyeing, however, the yarn is carefully inspected and all imperfections that would show in the finished cloth are removed. Whether dyed or not the yarn is now specially prepared for the looms.

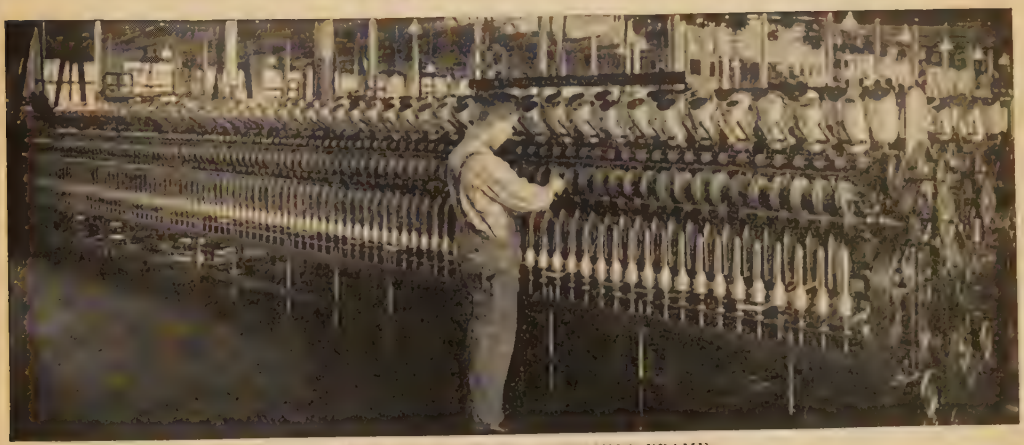
Warp threads, those which run lengthwise of the cloth, are usually "sized" by passing them through a trough which contains a sizing material such as gum arabic or corn-starch. Rollers attached to the trough squeeze the sizing into the yarn and also squeeze out the excess material. This operation strengthens the yarn and also prevents it from roughing up during weaving. The warp is now wound upon big reels and from these transferred to a large wooden roll, called the "warp beam", which holds all of the warp threads for the piece of cloth that is to be woven and these threads may number several thousands. The filling threads, which run across the cloth are wound upon shuttle bobbins, which in turn are placed in the shuttles. These bobbins are taken out and refilled as the process of weaving continues so that while the warp threads are continuous throughout the length of the cloth, the filling or weft threads must be untied whenever a bobbin becomes empty.

Modern weaving in its essential principles does not differ materially from that performed on the old-fashioned hand loom. The warp threads are paid out from the warp beam at one end of the machine and the finished cloth is rolled upon another roller at the other end of the loom. As the warp passes forward the proper warp threads are raised or lowered, as the shuttle passes back and forth carrying the weft, so that the desired pattern is woven. As each cross thread is put in it is hammered up against the preceding thread as in the old hand loom. But aside from these general features there is little resemblance between the old hand loom and its modern descendant, which is a marvel even among modern machines. After the warp has been

BEAMING, SPINNING AND DRAWING IN



BEAMING AND YARN INSPECTING



ENGLISH SPINNING — SPINNING FRAME

DRAWING IN WARP THREADS

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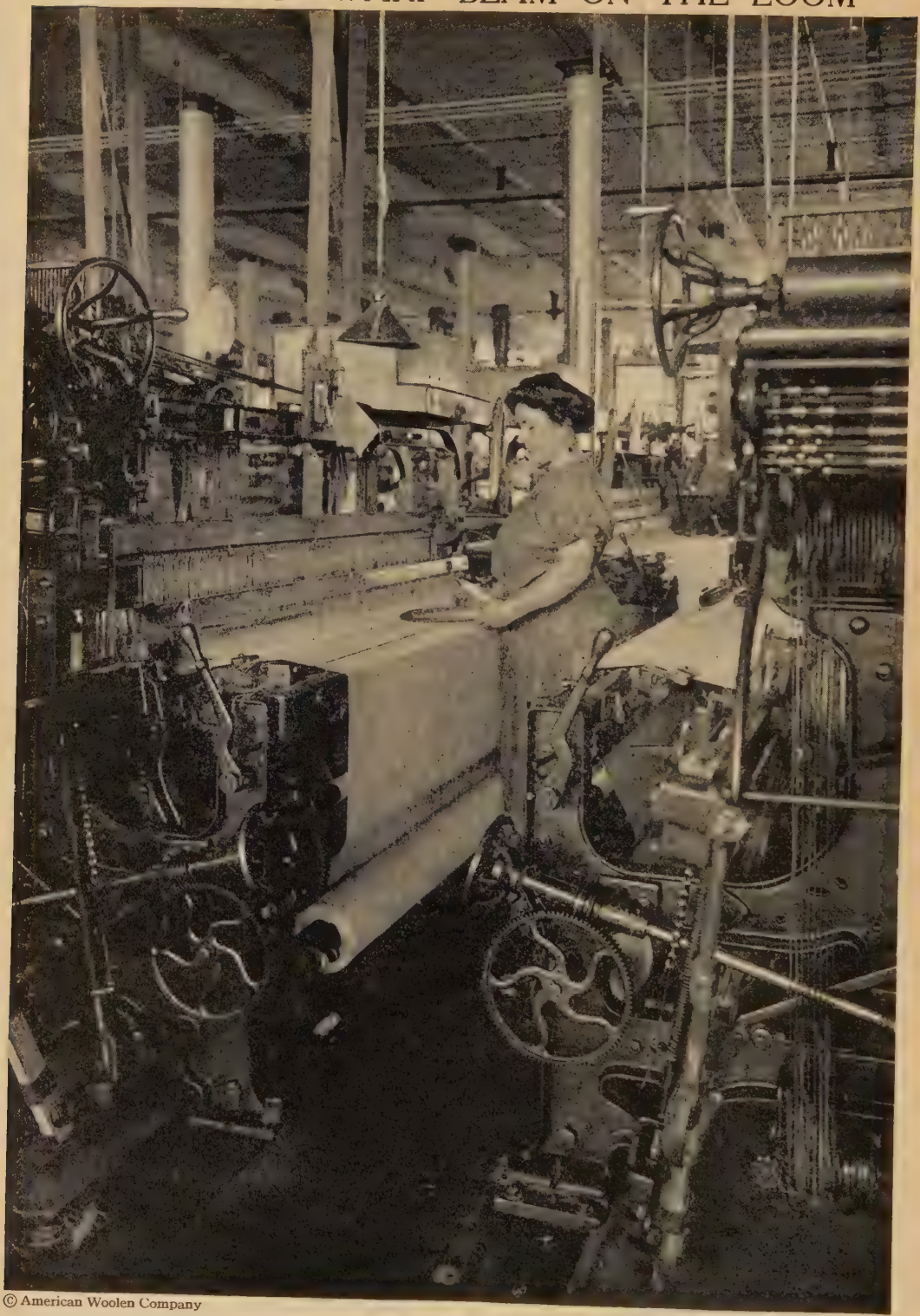
COMPLETED WARP BEAM ON THE LOOM



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drawn into the machine, the shuttles set and the machine adjusted, the performance is entirely automatic. The shuttles, of which there may be several, fly back and forth with lightning speed, the cloth flows from the machine and the entire operation is most fascinating to watch. A break in either warp or weft brings the loom instantly to a stop. The operator ties up the broken thread and the operation proceeds at once. On the whole the modern loom is as highly developed a piece of machinery as we have and certainly it stands near the top in point of usefulness.

The beauty of worsted cloth lies largely in the weaving and in the pattern. Worsted cloth when taken from the loom looks much as it will when in the finished state. Woolen goods, on the other hand, rely largely for their attractiveness on the finish which they receive after weaving. When the cloth is taken from the loom it is first carefully examined for imperfections and, by what is known as "burling" and "mending", any knots or threads that are wrongly woven are removed and any other imperfections that may be discovered are remedied. The cloth is then scoured and cleaned to remove all oil and other foreign matter acquired in weaving. While the processes of finishing are somewhat common to both worsted and woolen goods the operation of fulling is confined largely to woolens. This consists of

MARKING IMPERFECTIONS

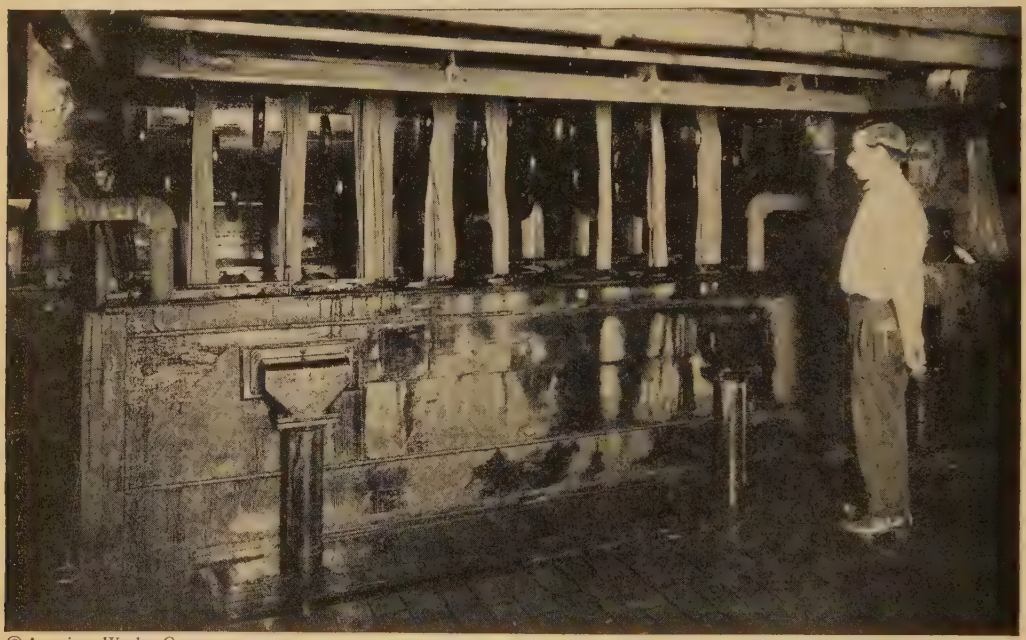
EXAMINING FINISHED CLOTH

© American Woolen Company

REMOVING KNOTS AND IMPERFECTLY WOVEN THREADS

subjecting the cloth to pounding or pressure while soaked with water containing a specially prepared soap, its object being to shrink and thicken the cloth, and for this reason cloth that is to be fulled must be woven much longer and wider than the required finished size. Thorough fulling may reduce the size of the cloth by a quarter or more. For this reason also the process is only applied to worsteds when it is desired to soften the weave, while in the case of woolens the weave is obliterated completely.

After fulling, the cloth is washed to remove the soap and is then carefully stretched and "tentered", which removes all the wrinkles and creases and sets the filling square across the warp. The process of "napping" comes next. This consists of sending the cloth through a machine in which the surface of the cloth is scratched by teazles, which is a vegetable product much like a large thistle blossom. The sharp hook-like points of the teazle rough up the surface of the cloth without danger of injuring it. Worsteds are napped only enough to brighten up the pattern but woolen goods have a nap raised upon them which obliterates the pattern. Woolen cloth is next passed through a shearing machine in which a long spiral knife something like the cutter of a lawn-mower shaves the nap to an even length. If the cloth is to be piece-dyed, as is the case with some woolens, this operation comes next and then comes the final finishing, which varies considerably with different products but which consists principally of brushing, steaming and pressing. Some cloth is put through the calender, which subjects it to a pressing action between highly polished, heated rolls. In another pressing process the cloth is folded with press-boards between each layer and the pile subjected to hydraulic pressure between heated plates. The finishing of worsteds and woolens varies widely with the character of the cloth, and variety is obtained by manipulating the nap. The sequence of processes outlined in the foregoing is to be taken as a general description only. A worsted fabric when finished has a clear, bright, well-defined pattern, seems close and firmly woven and has a decidedly dressy appearance. Wool cloths, on the other hand, are softer and more elastic, the weave is practically hidden by the nap and the general appearance is duller than that of the worsteds.



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DYE HOUSE — PIECE DYEING

FINISHING PROCESSES FOR WOOLENS

"RAISING" WOOLEN CLOTH, OR PUTTING ON THE NAP

STRETCHING THE CLOTH BEFORE IT IS DRIED

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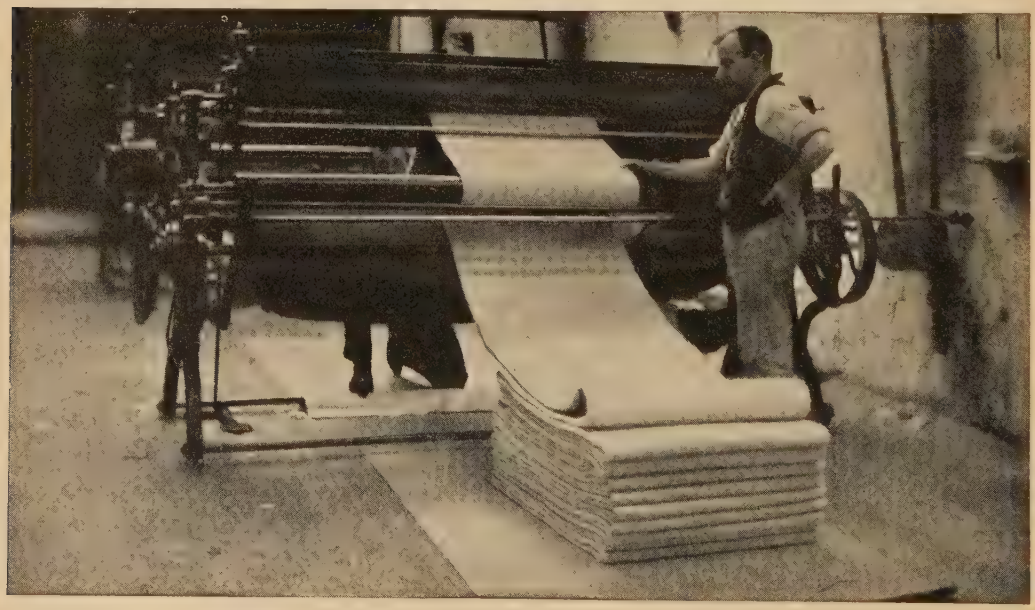
DRYING CLOTH

The woolen industry is, of course, very widespread in the European countries. Germany has many large manufacturing towns that are noted for woolens and worsteds, and France excels in fine woolens. Great Britain, however, has long been a leader in the industry both as to quality and price. There are many noted centers in England such as Leeds, Bradford and Manchester which are famous for their fine finishes; and Lancashire and Yorkshire are remarkable for the number of their woolen industries. Scotland is famous for its "tweeds" and "cheviots". Curiously enough, a considerable amount of handicraft weaving is still to be found in parts of Great Britain, and the cottage loom is still quite a factor in production. A considerable part of the wool industry in Great Britain is still carried on in small mills that do nothing but spinning or weaving. This practice of doing only one part of a textile process in any given mill and specializing on that, is more common in Great Britain than it is in the United States where the tendency is always to perform all the manufacturing operations from raw material to marketable product in one factory. In fact the first mill to make cloth from the raw wool was established at Waltham, Massachusetts, in 1831.

The principal wool-manufacturing states are Pennsylvania, Massachusetts, Rhode Island and New York. Philadelphia is perhaps best known among the cities as a wool-center, though Boston also has a great market. The largest single wool manufacturing organization in the world is also found in the United States. This is the American Woolen Company, which owns fifty-nine plants containing 10,000 looms. Among these mills is the Wood Worsted Mill at Lawrence, Massachusetts, which is the largest mill under one roof in the world. The total annual production of this company alone is over 70,000,000 yards of cloth. The employees number 45,000 and the capital stock of $80,000,000 is held by about 23,000 stockholders. The company manufactures all of its 30,000 different styles of worsteds and woolens from the raw wool to the finished product and sells directly to the manufacturing clothier and tailor.

No brief sketch such as the foregoing can give an adequate idea of the interesting and complex process of turning wool into cloth. One must really visit a great mill to fully appreciate this industry, and to see one of these great mills turning out miles of beautiful cloth daily is to see one of man's most wonderful and useful creations.



DRYING AND FOLDING THE COMPLETED PIECE

THE THING THAT MATTERS

The Astounding Discovery that Nations are Made up of Men and that the Foundations of Empires are Alive

THERE IS NO WEALTH BUT LIFE

OUR discussion of society, its history, organization, institutions and material equipment, has brought us around to a question more fundamental and ultimate than any of these, and at the same time fully as obvious. Yet, strange to say, it is a question which has only recently begun to be discussed or investigated in any serious, scientific way, and is hardly now on the road to being grappled with practically. As often happens in human affairs, so in the problem of social life and national destiny, the thing nearest home and most vital to the issues is passed over and neglected until late in the day. The question we speak of is that of the quantity and quality of the material of which society must be made, of its men and women. Surely it is plain that other questions, however important they may seem in themselves, are of trivial moment in comparison. The mystery is to explain why it has so long been passed over for the discussion of secondary and relatively insignificant public affairs. But so it is ever likely to be. We seem to be short-sighted creatures at best, prone to confuse means and end; "getting and spending we lay waste our powers"; while we are busy here and there, the *man* escapes.

We must admit that the reproach and rebuke of poet and seer are generally deserved. In a noble passage, Ruskin taught the political economists of his day that "there is no wealth but life". But life may be of many qualities, from the criminal to the saint, the idiot to the genius, the paralytic to the athlete. Hence it is evident that Ruskin's statement requires precision, definition and qualification.

Ruskin himself added the qualification, in many great passages, too little read. Not only is there wealth, there is also *illth*, as Ruskin pointed out; and whether we are studying the individual or the nation, this tremendous distinction requires to be made. For a nation, then, as for an individual, there is no wealth but life, and every society, state or empire is built upon living foundations, the quality of which, from generation to generation, is practically the determinant of everything else about which we may inquire in regard to that state or nation. With this commonplace and yet much neglected fact in mind, let us survey some of the great events and changes in the recorded life of man.

History is mainly the story of the rise and fall of races and civilizations. And the archæologists are now teaching us that prehistory is composed of the same tragedies. Though we cannot trace in detail the causes which produced them in prehistoric times, we can safely infer that then also they were ultimately biological, that for some reason or other the breed of men deteriorated and failed. Within the historic era, we need only cite the record of Greece and Rome and Spain, to exemplify the disaster that awaits the nation or people which in its concern for forms or things or achievements, fails to look to its human foundations. And unfortunately there are but too many examples in the conduct of modern nations to show the fatal effects of similar policies. But before we take up some of these in order, we must point out the fallacy of the ancient argument which was applied by the Greeks to explain the disappearance of races before

their time, and has since been applied to the Greeks in turn and to the other historic instances of decadence since the Grecian age.

The danger of argument from analogy in this as in other matters

This is the argument that races naturally and inevitably grow old, as individuals do. It is an admirable instance of the danger of what is called the "argument from analogy", a favorite method of Plato and Aristotle, to whom first we owe this idea about races. The argument from analogy asserts that because two things are similar in one or more points, they are similar in all. Races — or societies — and individuals are similar in many points, and therefore in all. Just, then, as the individual is mortal, runs this argument, so is the race. Each has its period of youth and growth, its maturity and finally its decadence, senility and death.

On the contrary, the science of life declares, as the capital fact which contrasts the individual and the race, that while the individual is naturally mortal, so far as "this mortal life" is concerned, the race is naturally immortal. The tendency of life is not to die, but to live. If individuals die, that is because more life and fuller is thus attained than if life bodied itself in immortal forms — they die for the immortal race.

"And the individual withers and the race is more and more"

But the germ-plasm is immortal; it has no inherent tendency either to degenerate or to die. Species exist and flourish now which are millions of years older than mankind. "The individual withers, the race is more and more."

The reply of the biologist to this theory of Plato's is, therefore, that the theory denies the one essential fact in virtue of which the individual is only the individual, and the race is the race — the one is made to pass, the other to remain. This fallacy of racial senility is nevertheless always cropping up, notwithstanding its evidently absurd character, and notwithstanding the positive evidence furnished by the countless races, animal and vegetable, which are known to have persisted for unthinkable ages. Doubtless races can be killed, for the germ-plasm, though naturally immortal, is not invulnerable; but it is one thing to assert that races die because they must, and another to assert that they die because they are killed. With this ancient error, this explanation which even if "true" would explain nothing, put wholly aside, let us glance at some of the historic cases of decadences, and then at a few of the problems and portents which confront modern nations.

The case of Greece; a fact and an ingenious theory

The fall of incomparable Greece, not after four thousand years, as in the case of Babylon, nor after such a long life as Rome enjoyed, has been the subject of the historian's wonder and comment ever since. Recently, historians and sociologists of the biological school have made the suggestion that the older historians have been able to describe, but never to explain this and similar cases, because they did not proceed from a due consideration of the ultimate vital basis of social life. Whatever the final explanation, the fact clearly seems to be that the collapse of political order and decline of every sort of achievement was due to a deterioration in the quality of the men of Hellas. With the passing of the men of genius embodying the creative power of Greece in the great age there were none to take their places. The following generations did not have the inherent powers, the capacity to dare and do great things. Many possible or partial explanations may be offered for the decline in human quality. Wars, foreign and civil, with assassinations, doubtless carried off some of the enterprising stocks. There was undoubtedly a general failure of the better classes to maintain themselves or increase, accompanied by a heavy loading of the population with the progeny of slaves. Probably of greater importance was a dilution of the Hellenic blood as aspiring and capable men spread over the East to seek their fortunes in the wake of Alexander's conquering armies.

A clever theory for explaining Greek decadence was announced by Mr. W. H. S. Jones in a book published in 1907, and based on the malarial studies of Sir Ronald Ross. The argument is, in brief, that the introduction of malaria into Greece caused the decadence of the population through racial poisoning. Evidence is brought forward that malaria was unknown in Greece during the great age. The disease has exceedingly striking features, and there is no word of anything like it in the authors of the time, and the characteristics and activities of the people are far from indicating a malarial population — of which we have an abundance of examples for study and comparison at present. It would appear that malaria was introduced, probably as a result of the military campaigns, and spread rapidly through the people, as its custom is when it gets the chance.. Secondly, there is the scientific evidence of the present time that malaria is a "racial poison", that it acts on the reproductive powers of afflicted persons so that their offspring are deficient in energy and have the marks of a degenerate population as compared with their immediate ancestors.

How modern human biology explains the decline and fall of Rome

In regard to Rome, the popular explanation of the historians is a biological one, but the modern biologist has to inform the historian that what he assumes does not happen. The historian has assumed that the characteristics of mind and body which people acquire in their own lives are transmitted to their offspring. Thus it is supposed, for example, that the son of a trained musician or linguist will have a special aptitude for music or language, not because his father had this aptitude as an inborn trait, which would be a good argument, but because the father trained and developed his talent. This is a very convenient line of argument and will explain nearly anything. In the case of a decadent nation such as Rome, the people, being too successful, are supposed to become idle and luxurious and unenterprising, and these characteristics, acquired by them, are supposed to become native in their children. In the same way, it is often argued, a race may be progressively improved. A few generations of discipline, and a race is produced which has discipline in its very bone. But, unfortunately, biologists of today are pretty well agreed that such transmission of acquired characters does not occur. Although it was believed in by Darwin and taken as a matter of course by Spencer, experiment has failed to confirm it and it is inconsistent with our best knowledge of the mechanism of heredity. Hence we must look farther and deeper for the explanation of the deterioration in the Roman breed.

Everyone is familiar with the mode of improving the quality of animals and plants by selection or "breeding" and everyone now knows Darwin's argument for the gradual upbuilding of races and species through the natural selection of the best adapted, or "survival of the fittest", in the struggle for existence. It is obvious that the same rule will work the other way just as well; if the superior individuals of each generation leave few or no descendants and the inferior are selected as the parents of the next generation, an inevitable deterioration will result. Was there such a principle of negative selection at work in the Roman population? Chancellor David Starr Jordan has argued that war was this agency and was to blame for the result. Rome was the great military nation of the world. Great wars succeeded each other and some "little war" was constantly in progress. Roman youth was required accordingly, and whom should the recruiting-sergeants want but the healthy, strong, brave, enduring? And whom should they reject but the diseased, weakly, puny and easily tired? We know the answer; and we must remember that those whom the recruiters rejected for military service they therefore in large measure selected for parental service. We can imagine them saying to the second-rate: "You are not good enough to be a Roman soldier; stay at home and be a Roman father!" No wonder, argues Dr. Jordan, that the children of such fathers wanted nothing but bread and games.

It seems an unavoidable conclusion that war must always have this effect of physical negative selection in a considerable degree. In the case of Rome, however, its reverse selection among fathers was only one of the influences at work. Solomon's assertion that "Righteousness exalteth a nation" may be taken literally and strictly in its application to the family and parental morality. We know how in Rome the moral standard fell, particularly among the upper classes. Marriage was dishonored, the use of drugs designed against the next generation was in great favor, and the standard of motherhood declined, while the cry went up that there was a shortage of soldiers of Roman blood for the legions. Aulus Gellius, writing about A.D. 150, which Gibbon regards as the critical period of the decline, describes how the mothers of his time were abandoning their natural duties, avoiding motherhood if possible, declining to nurse their babies when they had any, and calling any wet-nurse, "without inquiry as to her suitability, though, as is often the case, she may be diseased or addicted to drink". It is not hard to see why Rome fell when the Romans, or the cultivated and capable ones, died, leaving none of their kind to take their places.

How Spain was struck down by her enemies from within

Disease and racial poison may explain the decadence of Greece, war and moral relaxation that of Rome. In the case of Spain, it was ecclesiasticism, acting in a similar way. In the early modern era, Spain was the leader of the world. She produced great men of thought and of action and was the heir of the culture of Islam, of pagan antiquity and of the Renaissance. Her wealth was the envy of Europe; she owned most of the New World and considerable dominions in both the north and the south of Europe. But Spain fell. Her lingering hold on the last vestiges of her colonial empire was broken in the clash with us over Cuba in 1898. Rome had no more enemies to fear, and then she fell, struck at the heart, where empires rot. Spain also was stricken, not from without but from within.

The double action of ecclesiasticism was directed on the lines of reversed selection. Just as the Roman military authorities removed the physically best and their blood from the Rome that was to follow, thus selecting not the worthy but the unworthy for parenthood, so ecclesiasticism set to work, as if it were of deliberate intent, to root out of the Spanish blood the two great sets of qualities which are demanded for civilization, for national maintenance and progress. The Spanish Inquisition did its dire work in one direction; the ecclesiastical institution of celibacy — the negation of parenthood — as the highest human state, alone worthy of the highest human types, did no less disastrous work in the other direction. Between them they did their best, not in Spain alone, but in a less degree all over Christian Europe in the Middle Ages, to "brutalize the breed of our forefathers", as Galton phrased it in his celebrated work on "Hereditary Genius". "Thus as she (the Church) brutalized human nature by her system of celibacy applied to the gentle, she demoralized it by her system of persecution of the intelligent, the sincere, and the free." While the methods of the Inquisition were already in disuse in most of Europe by the time of the discovery of America, the Spanish Inquisition lasted until it was abolished by Napoleon in 1808. Its chief secretary gave the number of its victims as over 341,000 of whom about one-tenth were burned alive.

Two disasters for which France is paying heavily, and the menace to Russia

If we turn now to France, we find ecclesiasticism and militarism, twin enemies of human progress, both at work along the lines which Rome and Spain already illustrate. The deposition of France from its one-time primacy in European affairs is the consequence of two tremendous racial disasters, the expulsion of the Huguenots and the Napoleonic wars. The expulsion of the Huguenots parallelled in effect the Spanish Inquisition. Just those priceless human qualities of independence and enterprise which Spain squandered, France lost in her turn when the bigoted

court of Louis XIV brought about the revocation of the Edict of Nantes and eliminated the Huguenots from the French blood and breed. But there is one notable difference. Religious persecution deprived not only Spain, but mankind, in most cases, of the qualities for future generations which led its victims to their martyrs' graves. But religious persecution in France, though it led to much murder also, led chiefly to expulsion of its victims to other lands. Thus France lost as Spain did, but in this case other countries gained. A considerable number of Huguenots came to America and perhaps more went to Germany, but the chief gainer at the expense of France was England.

An examination of the records of the Huguenot families who settled there will show that they have added, out of all proportion to their numbers, to the intellectual and moral quality and to the substantial achievement of the English people. And when we consider that this was at the beginning of the decisive century and a quarter of rivalry for world dominion between the two countries, it is difficult to realize how different the map of the world might be today if France had employed a more liberal policy in this one instance.

The racial loss of the Napoleonic wars was of a somewhat different kind, on a very much larger scale, and with effects more difficult to estimate. Professor Richet, of the University of Paris, has computed that this series of campaigns must have cost in all not less than eight million lives. The drain upon the vigorous manhood of France was enormous, and of course involved a great fall in the birth-rate. The modern military tyrant practised as vigorous a reversed selection as any of his predecessors. He knew what he was doing and, like Frederick the Great, he tried to encourage physically fine fatherhood; but the effect of such measures is necessarily small in comparison with that of a national war. His battles had to be won, and he knew what kind of "cannon fodder" he wanted. It has been estimated for instance, that he reduced the average physical stature of Frenchmen by more than an inch.

The expulsion of the Huguenots was a disaster from the standpoint of the moral and intellectual qualities of the race; the Napoleonic wars, a disaster from the standpoint of physique.

In Russia, under the old régime, a kind of political ecclesiasticism or ecclesiastical politics was threatening to produce the same results as did the policy of the Church in Spain and France. "Holy Russia", with its huge population, its high birth-rate and vast physical resources, was one of the problems of the world. Yet only the ignorant supposed the backwardness of Russia as a whole to be due to any stupidity or deficiency in the endowments of the Russians as a people. On the contrary, the highest types of Russians are the equals of any men and women that can be found anywhere. Yet for decades Russia has been producing noble morals and splendid intellects only to export them. Year by year she sent the flower of her manhood and womanhood to Siberia, while many more, to escape a living death, exiled themselves, often becoming notable and honored in the countries of their adoption, including our own.

The lesson of history. Will the future be like the past?

Wherever we dip into history, we are struck with the recurring tragedy of racial decadence. Before the time of Spain we have the Saracens; before Rome and Greece there were Persia and Babylon and Egypt, of which we need only mention the names. Wherever we can adequately trace the history of any part of the earth's surface, we find that it was repeatedly and successively overrun and occupied by conquerors of this, that and the other race, who managed to oust established possessors, and yet could not maintain what they could win. No measure of success, no "far-flung battle-line", no bottomless coffers, no public buildings, no annual tribute of money or men or maidens, no glories of literature or art, no physical culture, no higher education of women, have availed in the long run to avert the fate of every great and successful nation or empire, from Babylon to Spain.

Where are we to seek for the cause of such tremendous changes? Cause there must be; and the doings which destroyed Rome and Babylon, the factors of this universal and recurrent tragedy called Decadence, must doubtless be essentially the same from age to age, whether in Asia or in Europe, or wherever else nations are born and grow and flourish and have no more external foes to fear, and then fall, struck at the vitals by some secret malady which no physicians could diagnose and no battalions overcome. It may be that races differ widely in their natural powers, so that some are destined ever to be masters and others to be slaves. But this is not what history shows. On the contrary, the same race is sometimes dominant and sometimes enslaved; and it is never so much in peril as when all peril seems past. In the history of nations, as of individuals, the paradox is incessantly illustrated that nothing fails like success.

The ever-growing mass of human beings and the "struggle for existence"

Everyone is now familiar with the great theory of biological development expounded by Darwin over half a century ago, but some peculiarities of its operation on the human plane are not so generally understood. In many ways the situation in the case of human beings is like that of other living forms. Every species, race or type in man, as in all other animals and plants as well, has a "tendency" to multiply indefinitely in a geometric ratio. As the number of creatures of any given kind which the earth will support is definitely limited, there results a constant pressure on the means of subsistence and a competition of type with type and strain with strain, to obtain the necessities for life and increase. Here, however, the resemblance between man and other forms of life ends, and three remarkable differences come to the fore, all of which are results of the unique intellectual endowments of our species.

In the first place, man's intelligence enables him progressively to subdue and *modify his environment*, including all other forms of life, to his own needs. Hence the capacity of the world to support human beings has been continuously and rapidly increased. In the second place, man's superior intelligence leads to his *organization* into societies. This organization greatly increases his efficiency in struggling against the difficulties of life, in both ways, *i.e.*, in competing with other men for the means of life and growth and in increasing those means through modification of the environment. Third and finally, intelligence gives to man a *new set of interests* beyond and above mere existence and multiplication; that is, he has a "standard of living".

The consequences of these differences are far-reaching in their effects on the character of the "struggle for existence" among human beings. The ability to modify environment has meant a rapid increase in the total number of human beings in the world through increase in the production of the means of living. Such a general increase does not take place in a "state of nature" or in the case of any other form of life, except through a decrease in the numbers of competing forms. But in the case of man it has gone on along with and even been the cause of a similar increase in the numbers of related types of life, which are used by man as food or as a source of power and an important aid in his struggle with lower nature. In the more "civilized" nations the increase in the means of subsistence has fully taken care of the biological increase and even more. The pressure on the environment has lessened and the standard of living been raised in spite of the growth in numbers. There is also a strong tendency for the more advanced races to "utilize" instead of exterminating the less advanced, so that they also have increased in numbers, partly through learning from their civilized competitors and partly for the same reason that the number of beasts of burden grows with progress in the arts.

The fact of social organization also has complicated effects. Within any society, the competition for the means of life is largely suspended; the group seeks to preserve its members and even assists those who are in straits. The "plane of

competition" is raised; the struggle between individuals or small groups gives place to a struggle between nations or large organizations. Then there is the further fact that the social feelings, — sympathy, consciousness of kind, instinct of mutual aid, or whatever we may call them, — developed within the social group as the basis of coöperation, tend to be extended to individuals in other groups. This process is immensely aided by the fact that during a period of rapid increase in productive power over the necessities of life through improvement in either social organization or technology, the "struggle" itself, even between groups, may be in abeyance for a considerable time.

The "struggle" between two struggles; the standard of life versus life itself

Most remarkable of all, however, among the effects of intelligence on the biological conditions of human life are those of the third factor we mentioned above, the emergence of new wants and their development into a scale of living over and above the demands of physical or vital efficiency. Among the lower forms or where "nature" and natural instincts rule, the sole aim of life is its perpetuation and increase. The rivalry which determines the survival of one type and the extinction of another is almost exclusively one of multiplication in numbers. The individual life matters little in itself; it is important as a means of giving life to a larger number similar to itself in the next generation. There is no such thing as "war", hardly a "struggle" at all in the direct sense; it is rather a contest in eating and breeding. There is among the higher animals considerable actual fighting over the right to exercise the reproductive function, but the "struggle" for food is much more like a foot-race than a fight, though there is some incidental real conflict. But in man, all this is changed. It is easy to see why under the rule of instinct one creature will not systematically prey on another of its own kind, because such conduct would defeat nature's purpose of increasing life. But man is a creature who "knows what he wants" and is likely to set about getting it by the way his intellect points out as easiest, without regard to the ulterior designs of nature behind those immediate impulses. Under the conditions of human life this easiest way, in appearance and even in fact, may very well be the path of organized predation.

A possible clue to the everlasting riddle of decadence

A still more serious consequence of man's having purposes of his own, other than nature's purpose of the increase of the type, is that the two sets of motives come into serious conflict. The maintenance of a "standard" involves the use of resources which might be employed in the increase of numbers. There is a conflict between quantity and quality, between life and the standard of life, a conflict for which there is no general solution, and which tends to become more and more acute. For presently, in addition to the necessity of choosing between the alternative ways of using a given limited quantity of resources, the very activities themselves begin to exclude each other. The mere fact of having a family even when resources exist in abundance may interfere with the use of superfluous income in ways which people come to consider very desirable — travel, culture, productive achievement in every field. It seems that we may have here a clue to the everlasting riddle of Decadence. It is quite probable that reasoning along biological lines in this way will enable us to understand why civilization has possessed the character of a self-limiting and self-defeating process and, to explain the recurrent displacement of peoples "higher" in cultural development by those who are "lower".

Just what are the limits to the survival value of quality in race

Of course there are limits, to the survival value of quality. Up to a certain point a nation or people undoubtedly gains in "survival power" as well as in the "higher values" themselves, by substituting ideals of quality for ideals of quantity and raising its standard of living at the expense of a possible increase in numbers. But that

point is rather quickly reached, and beyond, it must be apparent, disaster lies in wait; two sorts of things, either of them fatal, begin to come to pass. The relative decline in numbers of the more civilized as compared to the less, *i.e.*, of the nation with the lower standard, would alone be fatal, if long enough continued; and besides, the same sort of selective process operates within the more civilized society; the more cultured and capable classes similarly fail to maintain themselves relatively to the less capable, and the society is rendered impotent through the loss of competent leadership.

Alarming tendencies in modern nations. The handwriting on the wall

If you have a space filled with a gas at a pressure which represents, say, a billion molecules in every cubic inch, and next to it, with no substantial barrier intervening, another space filled with gas having only a million molecules to the cubic inch — well, no sooner do you have such a state of things than you have it no longer. The molecules from the region of high pressure will invade the region of lower pressure until the pressure throughout the space is made equal. The law of population pressure is precisely parallel to that of gaseous pressure. The crowd in which there is no elbow-room is always likely to expand, even in spite of railings. Barriers may be opposed to this pressure, in both cases; but if the difference in pressure goes on augmenting, the barriers are bound to burst. This is what is called in the one case an explosion, in the other, a war. If the barriers are more or less permeable, as they always are in both cases, we may have an instance of what is called "peaceful penetration", with the same final result but more gradually achieved.

Our present concern is to observe the consequences of population pressure when circumstances give its laws an opportunity to act. Of course it is not a simple thing like gas pressure. Why there should be greater pressure of men in one part of the world than in another; why the pressure should rise more rapidly in one place or time than in another; why it should even fall, of its own accord, in certain times and places, are questions to be considered. They depend upon matters of family life and birth-rates and death-rates and food supply, and upon changes in all these, and so upon a great complexity of more remote causes. But we can start with the well-known fact that population is increasing at some points faster than at others, and hence that population pressure is being constantly generated, and ask what follows. We are not entitled to assume that present conditions and tendencies will everywhere persist. High birth-rates may suddenly fall, and low ones may rise. New diseases may be introduced into populous countries or old ones become more deadly; exhaustion of natural resources or discovery of new ones or great advances in science and technology may change conditions fundamentally. But we are fully entitled to say that if the present tendencies, apparently well established and unlikely to change, persist, as may reasonably be expected, the distribution of population and of political power in the near future will be different from the present order in ways of which the man in the street has not dreamed, and of which it will be unpleasant for many of our readers to think.

What must happen if present population pressures continue to increase

Let us glance at a few representative cases in which a differential rate of increase in the numbers of human beings on different sides of a political boundary is leading to a constant increase in pressure. Before the outbreak of the Great War, Germany was adding eight or nine hundred thousand individuals to her population each year, and France was adding practically none. Yet France is a much more fertile territory than Germany, and well capable of supporting several times its actual population. Thus, even before the war, there was a steady and irresistible "invasion" of France by German people, which in the absence of war would have continued until equilibrium was restored. However great our sympathy with France on historical or humanitarian grounds, there

is no argument against the brutal logic of physical facts. Unless there are enormously great compensating differences, numbers must ultimately tell, the prolific people must inherit the land, and the redistribution of political power would be merely fitting forms to facts.

In much the same way, Germany in turn was trembling before the "menace" of the higher Russian birth-rate. England, too, was only relatively better off than France, for two children were being added to the population of Germany for every one added to that of England. France, and especially England, with great commercial empires and no surplus population to people them; and Germany, a poor country at home and a net increase in population nearing a million a year with no outlet of land inhabitable by white men — whatever our political likes and dislikes or our preferences between autocratic or militaristic and democratic or free systems of social organization, we must recognize that here was a situation inherently unstable.

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A MAN TO RECKON WITH IN THE FUTURE

Japan's rapid rise, and her dramatic bid for power in the modern world, are doubly significant when we remember the growth in her population. The birth-rate in Japan has nearly doubled since the war with Russia, which gave Japan her opportunity, but drained the nation of great numbers of men.

Reference to British colonies may suggest another contemporary instance, which presages tragedy in the not distant future if present tendencies are unchanged. In the "South Sea" lies the great island or continent of Australia, owned but not really occupied by English people. It should support, according to European standards, anywhere from ten to fifty times its present population, yet the population hardly increases. It (together with New Zealand) is the most extreme instance of the deliberate preference of a higher standard of individual life to increase in numbers. With every advantage, with no traditions or vested interests to handicap them, protected from aggression by distance and their connection with the British Empire, these populations simply refuse to increase.

Not only have they a low birth-rate, but in order further to safeguard themselves against the discomforts which follow from any appreciable pressure of population upon the food supply, they do not encourage immigration, and absolutely bar the Japanese. And what is happening in Japan? Though Japanese statistics must be accepted with some caution, it appears that in the last twenty-five years the birth-rate in that country nearly doubled, increasing from about 17 per 1000 to 31, and the bulk of this increase has taken place since the Russo-Japanese War. It seems to be a conscious action on the part of the intensely patriotic population to replace the enormous drain of manhood incident to that struggle, and to restore and augment the

political power of the Island Empire. It does not involve the rashness of prophecy to say that *if present tendencies persist,* Australia must ultimately be inhabited and governed by a Japanese population. For the Japanese as a race are by no means inferior, physically or intellectually, to the Caucasians. Anthropologists tell us that the typical Mongolian brain is heavier than the Caucasian, and not inferior in organization.

The situation of our own country. The internal problem of quality

We Americans are accustomed to point with pride to the unprecedented growth of our country in wealth and population, but a critical survey of the facts will probably reduce this feeling of elation. We have no dependable records of birth-rate or death-rates for the country as a whole, and have fairly accurate figures on net immigration for only a few years back, but it is possible to trace the general character, if not the accurate details, of what has happened.

Professor William F. Willcox's careful study of the indirect evidence of the census, especially the proportions of children to women of child-bearing age, leads very definitely to the conclusion that for a hundred years the birth-rate in this country has been falling at least as fast as that of France. Also, intensive studies of the data from some of the eastern states, where dependable birth and death records exist, have shown that the native population is not so much as maintaining its numbers, even though all born in this country are counted as native population and the large families of first generation immigrants are thus included. It must be concluded that, if the same facts hold over the rest of the country, we are rapidly ceasing to be an Anglo-Saxon people. Many other countries have similar problems of the relative or absolute decline in numbers of what is the dominant and presumably superior element of the population. In this country, the natural increase of the negroes is undoubtedly greater than that of the native whites. In Canada, the English-speaking element is alarmed at the much more rapid multiplication of the relatively backward French population. In South Africa, the Dutch increase much more rapidly than the English, and the Kaffirs much more rapidly than either.

When we turn from such broadly distinguishable elements as races or nationalities to the question of families or strains, definite data are meager, but there is little dispute as to the general character of the facts. It is indeed a commonplace that the successful individuals who attain high rank in any field of achievement leave on the average relatively few descendants — in the higher and more spiritual lines of endeavor quite commonly none at all, — while the race is perpetuated by the thoughtless animal spawning of the nondescript masses. We do not assume, of course, that reputation and visible success are always an accurate gauge of innate ability, but on the other hand no one will dispute that they are *some* indication. And if even this much is true the conclusion seems inescapable that civilization involves an acute negative selection which must mean degeneration and degradation in the inherent human quality of the breed. This would act rather slowly in reducing the *average* quality of the stock as a whole, but would reduce competitive efficiency much more rapidly through decreasing ability for leadership, which is the essence of organization. If race suicide and negative selection are inseparable results of a high civilization, we need surely look no farther for the explanation of decadence in history, nor need we hesitate to judge the future by the past. The question raised in the mind of the serious reader will naturally be, "What is to be done about it?" Unfortunately it is a question easy to ask and very hard to answer, but in our remaining chapters we shall glance briefly at the state of knowledge on the subject, the proposals that have been made and work that is being done.

This leads us to a consideration of the new science of *eugenics* which has attracted so much attention, occasioned so much controversy and called forth so much ridicule in recent years.

THINKERS VIII

BLAISE PASCAL — MATHEMATICIAN, NATURAL AND RELIGIOUS PHILOSOPHER
CHARLES SANDERS PEIRCE — FATHER OF AMERICAN PRAGMATISM
PHILO — A PHILOSOPHER AT THE CROSS-ROADS
PLATO — THE FOUNTAIN-HEAD OF ALL LITERATURES
PYTHAGORAS — THE FOUNDER OF THE CULT OF WISDOM
ERNEST RENAN — NOTED FRENCH ORIENTALIST
ANTONIO ROSMINI-SERBATI — FOUNDER OF THE ROSMINIANS
JOHN RUSKIN — THE FIRST TRUE "MASTER OF ARTS"

BLAISE PASCAL

Mathematician, Natural and Religious Philosopher

BLAISE PASCAL was the son of the president of the Court of Aids at Clermont, and he was born at Clermont-Ferrand June 19, 1623. His father, who was also his teacher, wished him to perfect himself in the languages and the principles of grammar and leave mathematics alone, but the boy could not be kept within such bounds, and set himself to work on geometrical problems without even knowing the names of the figures he employed. His definitions, like his names — "bar" for line, "round" for circle, etc. — were his own. And he was at work, self-taught, on a problem which forms the thirty-second proposition of the first book of Euclid when his precocious occupation was discovered, and he was given an opportunity to study "Euclid's Elements", which he understood without explanation, and to take a leading part in certain conferences which were the beginnings of the Academy of Sciences. His study of geometry, without interfering with the regular program of Latin, made such progress that at the age of sixteen he wrote a treatise on conic sections, in which he laid down a series of propositions, discovered by himself, that may be said to form the foundations of the modern treatment of that subject. This was never published but, something is known of it from a report by Leibnitz, and from a précis of its results published by Pascal himself in 1640 as "*Essai pour les coniques*".

The Pascals had moved to Paris in 1630 and the father incurred the disfavor of Cardinal Richelieu, when he joined the protest against the latter's reduction of interest return on the Hotel de Ville bonds of which he was a holder, and for some years was a fugitive cut off from intercourse with his family. An appeal from his youngest daughter, Jacqueline, who had appeared to advantage before the great cardinal in a girls' performance of Scudéry's play "*L'Amour tyrannique*", together with the recognition of her brother's genius, led to his recall and appointment as intendant at Rouen. It was at this time, due to overstudy, that Blaise Pascal developed infirmities that never left him. But in spite of suffering, he began those physical researches which resulted in showing that the height of a column of mercury in a barometer decreases when the barometer is carried upwards in the atmosphere. He himself conducted the necessary experiments in Paris at the base and top of the tower of St. Jacques, while his brother-in-law, under his direction, carried them out on a large scale on the Puy-de-Dome in Auvergne near his birthplace. Whether or no this experiment was due to a suggestion of Descartes — as the latter claimed — led to an undignified controversy among their friends and an accusation by the Jesuits, naturally not pleased by Pascal's success, that he was pretending to be the inventor of an experiment of which Torricelli was the author. Posterity has decided that Pascal is fully entitled to the credit of the

experiment and of the conclusions thereby established. The discovery was even more important as leading him to the general theory of the equilibrium of liquids, explained in his "Equilibrium of Fluids" (written before 1651, published 1663) and his "Weight of the Mass of the Atmosphere". "The most remarkable part of his treatise on the equilibrium of fluids," says Sir David Brewster, "and one which of itself would have immortalized him, is his application of the general principle to the construction of what he calls the 'mechanical machine for multiplying forces'." This new machine is the Hydrostatic press.

Pascal's treatise on the weight of the whole mass of air forms the basis of the modern science of pneumatics. He proved, by a balloon half filled with air and carried to the top of Puy-de-Dome (3000 ft.), that the mass of air presses by its weight on all the bodies it surrounds and that it is compressible and elastic. "His experiment and his treatise entitle him to rank with Galileo and Stevinus as one of the founders of the science of hydrodynamics" (Chrystal).

Pascal now returned to mathematical studies and wrote his treatise on the arithmetical triangle (printed in 1654 but only published in 1668) and on the cycloid, a famous curve that had been discussed by Galileo, Descartes and others before Pascal concentrated his attention on it and in a week "devised a method which embraced all the problems — a method founded upon his summation of certain series, of which he had given the elements in his writings accompanying his '*Traité du triangle arithmétique*'. From that discovery there was only a step to that of the differential and integral calculus, and it may be confidently presumed that, if Pascal had proceeded with his mathematical studies he would have anticipated Leibnitz and Newton in the glory of their great discovery" (Bossuet).

In quite another branch of pure mathematics Pascal deserves to rank as a founder. "The mathematical theory of probability and the allied theory of the combinatorial analysis were in effect created by the correspondence between Pascal and Fermat, concerning certain questions as to the division of stakes in games of chance, which had been propounded by the gaming philosopher De Méré" (Chrystal).

The above brief outline shows Pascal's claim to be remembered by posterity as a mathematician and physicist, in an age which produced Descartes, Fermat, Huygens, Wallace and Roberval. As Professor George Chrystal says, "Whether we look at his pure mathematical or at his physical researches we receive the same impression of Pascal; we see the strongest marks of a great original genius creating new ideas, and seizing upon, mastering and pursuing farther everything that was fresh and unfamiliar in his time. We can still point to much in exact science that is absolutely his; and we can indicate infinitely more which is due to his inspiration."

Religion now began to absorb the scientist, and practically put an end to his work in both these fields. It is not within the scope of THE BOOK OF POPULAR SCIENCE to treat of him as philosopher or man of letters. When his second "conversion" took place (1654) he associated himself, without ever becoming one of its "solitaries" or wholly observing its rule, with Port Royal, where his sister Jacqueline had for some time been a nun. And when the great Arnauld was accused of heresy by the Faculty of Theology of the Sorbonne, the aid of Pascal was invoked to make the public familiar with the case and he wrote the eighteen "*Lettres provinciales*", clandestinely published, immensely popular and successful, which brought down the wrath of the Jesuits and the civil authorities upon the anonymous author and which, however little modern interest the controversy arouses, remain as models of incisive style and brilliant wit.

The mortifying of a flesh never too strong culminated in Pascal's death on August 19, 1662. His subsequently published "*Pensées*" were fragments and notes of an Apologia in defence of the Christian religion and of Port Royal that he had long had in mind.

CHARLES SANDERS PEIRCE
The Father of American Pragmatism

CHARLES SANTIAGO SANDERS PEIRCE, American mathematician, logician and psychologist, was the son of Benjamin Peirce, the astronomer and mathematician who first demonstrated the fluidity of the rings of Saturn.

Charles was born at Cambridge, Massachusetts, in 1839. His father was for many years a professor at Harvard, and the boy received his early training in an atmosphere where thinking was precise and technical. He used to say that he grew up in a laboratory, and the keen exactitude of his work in logic is doubtless owing to the scientific environment of his boyhood. He was graduated from Harvard at the age of twenty, and from the Lawrence Scientific School four years later.

For many years he served as a research statistician for the United States Coast Survey. Notable among his services there was a valuable series of pendulum experiments, to determine the density and shape of the earth.

His writings are varied, and in a fragmentary way contributed brilliantly to the scientific thought of his day. His range of speculation was amazingly wide; he published valuable articles upon logic, psychology, metaphysics, mathematics, astronomy, optics, chemistry, engineering and other scientific subjects.

Although his style is often heavily burdened with technical terms and unwieldy constructions, so that he is difficult to understand, there is a rich reward for the thoughtful reader of Peirce's works. His philosophy is deeply satisfying, and there are in his memoirs and essays occasional rare passages of beauty and clarity that are, as Josiah Royce said, "flashes of brilliant light relieved against Cimmerian darkness."

In the winter of 1880–81 Peirce delivered a series of lectures in advanced logic at Johns Hopkins University, lectures that were devoted to an examination of the logical foundations of the leading scientific theories of the day.

In his own speculations he made fundamental the following three categories or modes of being:

1. Things — that is, individuals or particulars.

2. Objects of conception — that is, universals.

3. Signs.

These, he often said, constituted the essential feature of his philosophy. He was a student of inductive logic, which is the method of reasoning that proceeds from the specific to the general, and he maintained that an unequivocal definition of terms was the first requisite to any discussion. It was in reference to this rule that he first coined the word and defined the principle of Pragmatism.

His Pragmatism was a direct outgrowth of his readings from Immanuel Kant, of whom he was, especially in his earlier years, an earnest admirer. "The Critique of Pure Reason" and "The Critique of Practical Reason" were being widely read and discussed at the time. This is the precise way in which Peirce defined his maxim of Pragmatism:

"Consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then our conception of these effects is the whole of our conception of the object."

No one was more surprised than Peirce himself at the popularity given his maxim, later, by the writings of William James. It should be remembered that Peirce's definition of Pragmatism, though published, lay entirely unnoticed for twenty years, until James brought it forward. There was never the slightest disloyalty on the part of the younger man. He acknowledged many times, on the lecture platform and in print, that his ideas on Pragmatism were originally derived from Peirce; and we have come, therefore, to regard Peirce as the father of American Pragmatism.

But it was as a logician, not as a philosopher, that he wished to be known and remembered. His interest in human nature was keen and varied and he did contribute valuably to the study of certain psychological problems, but he never allied himself with any of the existing schools of philosophic thought, and he did not

dream of founding, or even of suggesting a new school, when he published his famous article on Pragmatism, in The Popular Science Monthly, in 1878.

When James revived the article, Peirce felt some apprehension, for, he said, "James is imbued with the ultra-sensationalism of the day. He refers all his ideas to the sensational side of experience." It was, therefore, a matter of concern to Peirce that the brilliant and popular William James was carrying the banner of Pragmatism so enthusiastically. The maxim, in the less precise minds of the younger psychologists and of laymen, was, he said, devolving into a sort of "Practicalism." So Peirce made James a present of the word "Pragmatism" and coined a new name for his own highly specialized principle, "Pragmaticism."

Peirce knew Darwin well. He was, of course, brought into close contact with the theory of evolution, in its early years, but he had no interest in it. As he himself said, he was too mathematical to be influenced by a theory that relied so heavily upon the element of chance to explain such phenomena as the origin of new species.

An important contribution made by Peirce to the world's knowledge of things technical is the scientific vocabulary of the first edition of the Century Dictionary. He contributed widely, also, to Baldwin's "Dictionary of Psychology and Philosophy" and similar works where his genius for exact definition was valued. He wrote also for "The Monist" and other scientific journals. His first published work was "Photometric Researches", 1878. While at Johns Hopkins he edited "Studies in Logic", written, with his help, by a group of his advanced students.

William James, Josiah Royce and Christine Ladd-Franklin were among his devoted and grateful friends.

During the spring of 1903–04 James, then Professor of Philosophy at Harvard, sent for Peirce to lecture at the Lowell Institute. He was a member of the National Academy of Sciences, and a fellow of the American Academy of Arts and Sciences.

He died at his home in Milford, Pennsylvania, April 14, 1914.

PHILO
A Philosopher at the Cross-Roads

PHILO JUDÆUS, the great Jewish philosopher of Alexandria, who, contemporary with and immediately following Christ, succeeded largely in interpenetrating the speculative philosophy of Greece with the supernatural revelation of the Jews, was born at Alexandria, probably between the years 20 and 10 B.C. His family seems to have been rich and influential, for Josephus mentions that his brother was an important farmer of taxes. Alexandria at that time was a huge, cosmopolitan city, with an enormous population of Jews. It was a very great educational center, and, in matters of thought, the chief meeting-point of East and West.

Philo seems to have absorbed all the learning of Greece, to have been intimately acquainted with the works of Plato, and to have regarded the philosophies of the Stoics and Pythagoreans with unbounded respect. The interfusion of his own ideas with those which he had assimilated from the Greek philosophies resulted in an original philosophy in which Greek thought was leavened by Oriental mysticism, and the amalgam had further an important influence on the growth of Christianity.

What personal touch Philo had with Christianity is not clear. It is known that he visited both Rome and Jerusalem. At the age of more than fifty he went to Rome as the spokesman of a Jewish embassy from Alexandria to plead for the revocation of the decree which demanded that every race within the empire should pay divine honors to the Emperor Caligula. Of course, that was impossible to the Jews. Philo gives a graphic description of his visit in his "*De Legatione ad Caium*". Eusebius and other Fathers of the Christian Church preserve the tradition that he again went to Rome, and on this second occasion made the acquaintance of the Apostle Peter, but critical opinion receives the statement with doubt. Here the personal story of Philo ceases, but a selection from his works remains, and the influence of his thought is remarkably widespread. Its most familiar form

appears in the difference in spirit between the Gospel according to St. John and the other Gospels. Obviously, St. John's Gospel is interpenetrated by the influences of the Alexandrine thought which proceeded from Philo.

Minute examinations of Philo's writings have been made by Schürer, Zeller and others, so that his system has received the appreciation its importance deserves. The intellectual Jews of Alexandria had long been deeply involved with Greek thought, and had been seeking to find some ground for reconciliation between their conception of the Eternal and the purest Greek ideals. The Pentateuch had been translated into Greek, and a Jewish-Greek literature had sprung up. Indeed, so marked was the Greek influence that many of the Jews had forgotten their own language, and become Hellenistic in speech, nationality and culture. Thus, while Rome ruled imperially, Greek thought and artistry dominated the world. Even Philo cannot be regarded as a profound Hebrew scholar.

But the Jews, though Hellenized, clung to their religion, and tried to give it a wider influence by grafting it on Greek culture. They were even prepared to tone down or allegorize the literal rendering of their Scriptures if by doing so they could recommend the central features of their creed. Philo felt all these influences, but as regards his faith was conservative. He was Jewish to the core, regarded the Jewish law as a divine institution, and brought all philosophies to it as a test. The laws of Moses were his final court of appeal, and he held that the best and truest doctrines of the Greek philosophers had long ago been incorporated in the Jewish Books of the Law.

If, as he had learned from the Stoics, human knowledge was delusion, then man must search for truth in another sphere. If Reason fail, there is still a faculty that can supply man's want, and that is Faith. True science is God's gift, and it springs, he held, from piety. Philo's idea of God was that of a Being indefinable, unimaginable. Finite beings are circumscribed by their attributes. God is without limits; He has no attributes. He is one; simple; everlasting; immutable — better than Platonic Virtue, or Knowledge, or the Beautiful or the Good. He cannot be otherwise if He exists. But no one can fathom the mystery of His Being — "I am that I am." But, if it is impossible to know God in His essence, there are intermediary divine forces or ideas that establish an active relation between God and the world. These intermediary entities, says Philo, are identical with the "angels" of the Jews — "a chorus of unembodied souls" occupying the air, messengers of God, through whom He communicates with finite beings.

Philo regarded all these intermediary ideas or forces as comprised in one supreme idea — the Word, or Logos — God's thought, the immanent reason of God. Now, the Greek word "λογος" means both "reason" and "word", so the doctrines of the Logos may be construed in two ways — the one Hellenic and metaphysical, the other Hebrew and theological. And it is also used in the Gospel of St. John in a third way, where the Logos, the Word, "the first-born son of God, and mediator between God and man", is made flesh, and "dwelt among men" in the form of Christ. Thus Philo's thought is the gathering-ground where Greek philosophy, Hebrew theism and systematic theology met. The Alexandrine Jews thought to impregnate and capture Greek thought, but a third competitor dominated the amalgamation; and the elaborate philosophy of the Christian Fathers was built on the interaction of Greek and Jewish thought around the simple life of Christ and His childlike teaching of a Father in heaven. No man has ever stood more certainly than Philo at the cross-roads of historic thought.

PLATO

The Fountain-Head of All Literatures

PLATO, from whom, according to Emerson, come "all things that are still written and debated among men of thought", was born about the year 427 B.C., either at Athens or in the island of Ægina, of an aristocratic family, with Solon as an ancestor on the maternal

side. In the fullest possible sense, according to the Greek ideal, he was an educated man, physically and mentally. Quite early he became devoted to philosophy, and at the age of twenty was a disciple of Socrates, whose discussions he attended for eight or ten years. He was present at the trial of Socrates, but not at his death.

Afterwards he traveled extensively, but not as widely as the accretions of tradition would lead us to suppose. He visited various parts of Greece, Egypt, Asia Minor and Italy, and thrice went for special purposes to Sicily. His object in the first case was to visit the tyrant Dionysius I of Syracuse, but Dionysius sold him as a slave. He was, however, "bought in" by a friend and redeemed. He went again to try to induce Dionysius II to establish a Greek colony in Sicily, on a model he would draw up, but he failed. A third visit was to make peace between the tyrant and Dion, who had befriended Plato when he first ventured to Syracuse.

When about forty years of age, Plato settled in Athens, and began to teach in the grove named after Academus, and there remained for about forty years, the leading thinker of the world. He died in his eighty-first year, in 347 B.C., according to some at a wedding feast.

Plato inherited the nucleus of his teaching from his master, Socrates, and particularly his method of discourse; but he broadened his thought constantly during his travels and studies, and so far developed his philosophy that many of his tenets held in later life were inconsistent with his earlier teaching. The discussions carried on by word of mouth in the academy were given a literary form in dialogues, which, in the philosopher's prime, were examples of rare beauty, even when they were most closely reasoned. In later years the style became more severe, with an approach to baldness. Apparently all the writings of Plato have been preserved, but some attributed to him are admittedly spurious. There is no question, however, respecting the authenticity of the most notable of his productions.

Plato did not build up a complete system of philosophy; rather, he established a method of thought with certain fixed leading ideas. Often he discussed subjects — particularly in the earlier part of his life — with a view to the exclusion of error, by Socratic questioning, but did not attempt to sum up the truth as it finally appeared to him. Indeed, singularly little of Plato's writing, apart from certain fixed conceptions which run through all his Dialogues, can be said to embody personal conclusions. Various views are expressed by him as if in controversy, and the main points are allowed to remain open, after unsound opinions have been excluded. In only one Dialogue does Plato himself appear as a talker — in the guise of an Athenian stranger.

To Plato the phenomena of the world which are observed by the senses are only temporary images of real existences which are eternal. To him abstract ideas were the sole realities, and the consideration of them alone constituted philosophy. These abstract ideas, such as goodness, greatness and beauty, had, in Plato's opinion, a separate existence. They were the substantial forms of which the things men call tangible are only appearances. Aristotle names the one set of appearance "sensible objects", and the other "intelligible essences". It is in these intelligible essences that existence is to be found, and they alone are worthy of the contemplation of true philosophers. The things we call real, because they take form in matter, are only blurred copies of the genuine realities which are *ideas* and eternal.

So, too, is the soul immortal. That is why it has glimpses of the eternal realities, the full truth of which can only be seen by the gods; and we secure those glimpses with greater or less clearness in the proportion that we are like the gods. We are born, Plato argued, with recollections of eternal truths that have been known to us in previous existences. God represents the supreme idea of all existence — is the Great Intelligence and the Source of Intelligences. The bond which unites the human and Divine is love — the longing

THE FOUNTAIN-HEAD OF KNOWLEDGE

PLATO TEACHING HIS FOLLOWERS IN THE "GROVES OF ACADEME", AT ATHENS

of the soul for Beauty, and Beauty is the most vivid image of Truth.

Is this very ethereal? Well, Plato was a hard reasoner on ethereal things. As George Henry Lewes says in one of the most elequent passages in his "Biographical History of Philosophy": "He did not look on life or on the world with the temporary interest of a passing inhabitant. He looked on them with an immortal soul longing to be released from its earthly sojourn, and striving to catch by anticipation some faint glimpses of that region of eternal Truth where it would some day rest. The fleeting phenomena of this world he knew were nothing more. But he was too wise to overlook them. Fleeting and imperfect though they were, they were the indications of that eternal Truth for which he longed — footmarks on the perilous journey, and guides unto the goal. Long before him had wise and meditative men perceived that sense-knowledge could only be knowledge of phenomena; that everything men call existence was but a perpetual flux — a something which, always *becoming*, never *was;* that the reports which our senses made of these things partook of the same fleeting and uncertain character. He could not, therefore, put his trust in them; he could not say that Time was anything but a wavering image of eternity. But these transitory phenomena were *images* of true existences. Interrogate them, classify them, discover what qualities they have in common, discover that which is invariable, necessary, amidst all that is variable — discover the One in the Many, and you have penetrated the secret of Existence".

Plato never really came down from this lofty region of philosophical speculation, which to him enshrined a faith. When, as in his "Republic", he attempted to put his thoughts into a practical form, there was a strange unreality in his purely intellectual proposals. We may accept his wisdom, fortitude, temperance and justice as the supreme human virtues, but what can we think of the mind which formulated these lofty conceptions also suggesting that the rulers of the State should give that State its religion — a proposal which would sanction all persecutions? What can we think of his banishment of poets and musicians from his ideal State? Above all, what can we think of his abolition of all the responsibilities and joys and duties of parenthood and family life — children being unknown to father and mother, and belonging to the State alone? Plato was too transcendental a philosopher to understand human nature, which, after all, more than anything else, makes the world of ideas to move.

His influence in his own day was enormous, and his influence as a connecting link between the thought of the East and the West was greater centuries after his death, and has even had a strongly modifying influence on philosophic Christianity. As Emerson said in the essay already quoted: "Plato's books are the fountain-head of all literatures. He is the mountain from which the drift-boulders of debate have been detached. No wife, no children, had he, but all the civilized nations are his progeny, and tinged with his mind. His writings make it impossible to think on certain levels except through him. He came to join, by contact, the infinity of Asia with the definiteness of Europe. He keeps two vases by his side, one of ether and one of pigment, and he invariably uses both. He paid homage to the illimitable, and added, 'And yet things are knowable'. He saw nature, he saw culture, but said, 'There is also the Divine'."

PYTHAGORAS
The Founder of the Cult of Wisdom

PYTHAGORAS was born near the beginning of the sixth century before Christ, in Samos, and died at a great age, probably about the year 500 B.C. Very little, however, is known of his life, though myths abound. It seems certain, at least, that he visited Egypt, with which Samos was in close intercourse, and learned something from the priests there. But a man of such magnificent mind needed little help from priesthoods, and we need not question the essential originality of his teachings.

Somewhere about the year 530 B.C., Pythagoras founded a school at Crotona, in Italy, and there he and his disciples practised the moral and religious principles of Pythagoreanism. The heart of this doctrine is expressed in the word "philosopher", a lover of wisdom, which Pythagoras invented in order to describe himself. He preferred not to call himself a "sophos", or wise man, like his contemporaries and predecessors, but a "lover of wisdom". To this high passion Pythagoreanism is devoted. Ordinary worldly pleasures are to be abandoned, and the whole being of the initiate is to be devoted to the rapturous pursuit of true wisdom. Such a doctrine was, of course, opposed to the popular religions of the day, and its followers ultimately had to flee from popular fury.

The novice who sought to enter the society of Pythagoreans was condemned for five years to silence; he had to undergo many humiliations, to test his powers of self-denial; and, finally, to begin the study of wisdom with mathematics. In this science Pythagoras excelled, and our knowledge of the properties of numbers almost begins with him. Hence we need not be too incredulous if tradition attributes to the Pythagoreans a knowledge of astronomy which was far in advance of their times.

Much of the teaching of Pythagoras was mystical. He taught that the spheres, as they roll, make music, and popular rumor declared that he, the more than earthly philosopher, could actually hear the harmony of the spheres. But he made practical discoveries, too, and is regarded as the founder of the art and science of music. The Greeks used a stretched string, which they called a "monochord", and which produced a musical note when it was plucked. Pythagoras applied his theory of numbers to this monochord, we are told, and discovered how the note is raised an octave if the length of the string be halved; and how, also, if a stop be inserted one-third of the distance along the string, a note and its octave will be produced from the two parts of the monochord thus divided.

Most celebrated of all is the doctrine of the transmigration of the soul, which was taught by Pythagoras, and which he may possibly have derived from Egypt. A notable reference to this celebrated theory is to be found in "Twelfth Night", in the colloquy between Malvolio and his persecutors.

The Pythagorean society at last became very powerful. The philosopher lectured to women as well as men, his wife herself being a philosopher. The popular voice acclaimed the wisdom of so venerable and unprecedented an order — for a time. His society became a political power, not only in Crotona but in many other cities. Pythagoras chose young aristocrats of both sexes for his disciples, and sought to establish a mighty school of wisdom, where the best of men and women might become better. But of course his followers were unworthy of him. They wanted ordinary secular power, though "his was the ambition, not of a hero, but of a sage". Finally, the people rose, many Pythagoreans perished, and it is doubtful whether his enemies destroyed Pythagoras, or he died, a fugitive, among his disciples. But his name, his life, and his teachings have helped to exalt and ennoble the history and the thought of mankind for nearly two thousand five hundred years.

ERNEST RENAN
A Noted Orientalist

ERNEST RENAN, a noted surveyor of all the religious thought that had its origin in the Hebrew race, was born at Tréguier, in Brittany, on February 27, 1823. His father was a Breton, his mother of Gascon descent. The former died when his son was five years old, and the boy's upbringing was largely due to his sister Henriette, who was twelve years older than himself. The story of man contains no more beautiful instance of brotherly and sisterly affection and coöperation.

From the first the aim was to prepare the boy for the priesthood, and in this the local Fathers helped to the utmost. They taught him till he carried off all the school prizes, and at the age of fifteen the echoes

of his cleverness reached M. Dupanloup, who was training men of influence for the priesthood through the College of St. Nicholas du Chardonnet. There, and at the Seminary of Issy and the College of St. Sulpice, he studied philosophy and philology and Hebrew till he was twenty-two, but by that time he had come to the conclusion that the Church was not for him. It was from his study of the Oriental languages, he declared, that his doubts grew beyond repression; and finally Henriette, who had made great sacrifices to give him a career in the Church, advised him to do what he most strongly felt to be right. So he entered a lay college as a teacher, and at the age of twenty-four made his mark in literature by a "General History of the Semitic Languages".

After some years' service as a teacher, Renan secured a post at the National Library, and began writing for the *Révue des Deux Mondes* and the *Débats* essays which attracted much attention by the charm of their style and their freshness of treatment. Later, these essays were published as "Studies in Religious History" and "Moral and Critical Essays". Studies and translations of the Book of Job, the Song of Songs, and, later, Ecclesiastes followed, and, the chair of Hebrew falling vacant at the College of France, Renan was admittedly the best suited for its occupancy; but Napoleon, fearing the offense that would be given to the Church by the appointment of one so unorthodox, despatched him on an archeological mission to Phœnicia. He was accompanied by his sister and wife, for he had married a niece of Ary Scheffer, the painter. His wife returned home, but Henriette stayed with him during his trying Eastern travels, and died in Syria in 1861.

The book he wrote about her, "My Sister Henriette", is one of the most beautiful of all literary family records. On his return to France, broken in health, Renan was appointed to the chair of Hebrew, but was almost immediately moved out of it for describing Christ as "an incomparable man". He refused the post of sub-librarian of the National Library, and thenceforward lived by his pen alone.

The first of his books after giving up official employment was the "Life of Jesus", of which 60,000 copies were sold in less than five months. Renan now set himself the task of writing the early story of Christianity, bringing it down to the time of Marcus Aurelius, and also the history of Israel. He was always busy, too, with miscellaneous writing, and one of the styles he used in dealing with philosophy was a revival of the Greek dialogue.

When he was sixty, Renan published his early biography, looking at the influences that shaped his own life and character much as he would have done had he been summing up a historical personage. He held that the surroundings of his early life in Brittany, where anyone could watch "a fact grow into a faith", specially fitted him to understand the accretions by which religions have been built up.

He passed away on October 12, 1892, declaring that he had done his work, and so died happy. There is no doubt that at the time of his death he was the most widely read serious prose-writer in Europe, but it is very doubtful whether his writing has the qualities that will give it a lasting value. He popularized the study of the language and the early story of the Jewish people, but he did not show in his work as wide and sure a scholarship as has since been brought to bear on his favorite subjects. His popularity was due in a large degree to a singularly bright style, that invested all he wrote with an almost romantic air, but he often failed in taste, and he had the fatal weakness of raising doubts as to his own sincerity. His opinions on many subjects were constantly in a state of flux, so that no reader could ever be his disciple, however interested he might be in his writings. Sometimes Renan fell into sheer cynicism respecting the inmost intimacies of his own beliefs, as when he said that the most logical attitude towards religion was to behave as if it were true. He brought a picturesque mind to the study of religions in an age of changing methods, and his writing will remain interesting, notwithstanding its lack of profundity and of reverence, for he knew no Holy of Holies.

ANTONIO ROSMINI-SERBATI
Founder of the Rosminians

ANTONIO ROSMINI-SERBATI was born on March 24, 1797, at Rovereto in Austrian Tyrol. He studied in his native province, but eventually completed his studies at the University of Padua. He manifested an especial interest in philosophical speculation. He was ordained priest in 1821. In 1828 he established his celebrated Institute of Charity, the members of which are often called Rosminians. It was a religious congregation which was primarily concerned with works of charity, and hence its name. Rosmini soon became well known and influential in Italy. In 1848 King Charles Albert of Piedmont sent him to Rome to induce the Pope to support Italy against Austria. Rosmini was quite in favor of a United Italy and was in sympathy with the national aspirations of the Italian people. Pope Pius IX recognized the ability of Rosmini and appointed him minister of instruction in his cabinet. However, after the political upheaval in Rome in 1848 Rosmini lost the favor of the Pope and the celebrated Cardinal Antonelli superseded him as adviser of Pius IX. Rosmini thus ended his diplomatic career. He now retired to Stressa near Lago Maggiore, devoting himself entirely to his religious society and to his philosophical researches. He now led a calm and virtuous life until his death, which occurred at Stressa on July 1, 1855.

Rosmini taught that philosophy is the science of the ultimate reasons or grounds of knowledge. Thus his philosophy is largely concerned with the vexing problem of human knowledge. He holds that the fundamental act of the human mind is intuition, which appears to be a rather passive state of the mind in which it comes in contact with the intelligible object. The object of intuition is ideal being. It merely enlightens the intellect without exciting any stimulus upon it. Ideal being is objective, hence outside of the mind. Rosmini asserts that it is universal, necessary, simple, immutable, eternal and identical for all minds. Yet he holds that it is not to be identified with God, it is only an appurtenance of God. He also asserts that the idea of being is innate in our minds and prior to all knowledge. It is difficult to see how Rosmini could distinguish his Ideal Being from the Deity. It is quite apparent that his doctrine is a sort of Ontologism, and that it at least verges on Pantheism. Rosmini himself admits that his teaching is quite similar to that of Malebranche.

Rosmini teaches that besides intuition there is another act of the mind which he calls reason. By reason the mind becomes acquainted with real being which, unlike ideal being, is particular, contingent, manifold, variable and temporal. The individual real beings act on our senses and we recognize those activities as manifestations of ideal being previously known by intuition. Knowledge, he says, is a judgment by which we predicate existence of real beings felt or experienced by us.

Logic, according to Rosmini, is the science and art of reasoning. It should lead us to the possession of truth which is identified with being. When we know the being of a thing we attain truth. Error is reflection deviated by the influence of the will. Logic is to show us how to use reflection in order to avoid error.

Cosmology and psychology are the sciences of perception, whereas the sciences of reasoning are ontology and natural theology, or the ontological sciences, and the deontological sciences whose object is the perfection of beings. Psychology is concerned with the ego, considered apart from its accidental accomplishments or attainments. The spiritual principle in man is both intellectual and sensitive. The body is felt directly by the soul and immediately perceived by it. The human soul or spiritual principle in man is immortal and hence can continue to exist even although the body is destroyed.

Cosmology is to study the visible universe or the non-ego. Ontology has as its object the study of being in all its relations. There is one being which is the object of a special ontological science.

That being is the Absolute Being, or God, and the science is natural theology, or theology based on philosophy and science alone and not on revelation. Our knowledge of the Absolute Being, or God, is negative, we rather learn what God is not than what He is. However, the existence of the Absolute Being can be definitely proven.

Moral philosophy or ethics is the most important of the deontological sciences. It is the science of virtue. Man possesses free-will and hence is able to cultivate virtue. Free-will is the ability to choose between objective good and subjective good, or between duty and pleasure. Man should, of course, select duty and endeavor to become united to the highest good or God.

Rosmini's philosophy has exerted considerable influence in Italy. Numerous philosophical propositions culled from his works have been condemned by the Church. Whatever estimate one may place on his philosophy, one must admit that he was an earnest, sincere and indefatigable searcher for truth. He is perhaps the greatest modern Italian thinker and his writings exhibit a high degree of originality. He was a very prolific writer covering an extensive range of subjects. Some of his more important works that have been translated into English are: "New Essay on the Origin of Ideas"; "The Principles of Moral Science"; "The Restoration of Philosophy in Italy"; "The Philosophy of Right"; "The Ruling Principle of Method Applied to Education"; "Maxims of Christian Perfection"; "Psychology".

JOHN RUSKIN

The First True "Master of Arts"

JOHN RUSKIN, one of the greatest personal and intellectual forces in the era of Victorian thought, was born in London on February 8, 1819, of Scottish parentage. His father and mother were cousins of very mature age. The father was a very successful sherry merchant. The parents made the education of their son the principal feature of their middle age, the mother training him in godliness and the Bible, and the father taking him on his many journeys throughout Great Britain and abroad, and stimulating his love of nature, art and literature. Nearly all the main features of Ruskin's later life were the best-developed interests of his boyhood.

He was one of the numerous infant prodigies who have neither died young nor been flashes in the pan. He could not remember learning to read and write. As an infant he wrote poetry. At fourteen he had the passion for the Alps which never left him. At eighteen he had already begun his defense of Turner as a painter. And from the first he was a stylist, his father, while reading to him in early boyhood, calling his attention to the cadences of fine prose.

Ruskin's regular education was desultory in a high degree. He never made exact scholarship an aim, but he went to Christ Church, Oxford, as a gentleman commoner, enjoyed the society, took his degree and won the Newdigate prize for English verse. He is one of the great writers who, happily, has told, in his "*Præterita*", the story of his own youth.

Ruskin's miscellaneous education included a varied training in art. He studied painting with some of the best-known painters of his day, and practised drawing with the greatest assiduity, till he attained a most minute and delicate skill, but he never attempted to compose a picture. Drawing, for him, was an art by which he preserved, exactly, the sight of something he admired. At the age of twenty-four he published the first volume of his "Modern Painters" — a work designed to show their superiority over the Old Masters. Perhaps it would be better to speak of the volume as the first "draft", for afterwards it was reissued, altered considerably, and this introduces us to one of Ruskin's many peculiarities. He was never satisfied with what he had written, but kept altering it from time to time, sometimes for the worse. The "Modern Painters", though not generally acceptable to the painters of that day, proved conclusively the coming of a great critic and a great master of English. It contained descriptions of objects of natural beauty unequaled.

Though Ruskin's writing often grew too elaborate, and was weakened by a sweetness that seemed deliberately manufactured, at its best it suggested the myriad delicacies of his marvelous appreciation of every form of beauty. To many of the lovely harmonies of nature that charm beyond speech he could put a speech that was artistry.

From painting he turned to architecture, and at the age of thirty published "The Seven Lamps of Architecture", and, two years later, "The Stones of Venice". His first printed writings had been on the "Poetry of Architecture", in Loudon's *Magazine of Architecture*. Ruskin unquestionably modified greatly the modern conception of both painting and architecture, and brought into it a reality as well as beauty that had been missing. He was the first sincere and competent art critic. He united his criticism, too, with extremely useful teaching, as in his "Elements of Drawing" (1857) and his "Elements of Perspective" (1859).

But by 1860 he had finished his work in relation to formal art, though he was elected professor of art at Oxford in 1869, and held the office ten years. His view of art was inextricably mixed up with morals, religion, industry, political economy and all else that interests man, and he turned aside to discuss these things, as a lecturer and as a writer, till he lost himself in a whirl of ideas that often had no clear connection with his life's work, except that they always were artistically presented.

As soon as he branched away from his essential work as an art critic, Ruskin adopted, and ever afterwards clung to, the fad of using for his books titles that do not indicate in the slightest degree the contents of the books. "A Note on the Construction of Sheepfolds" was the first venture in this direction, the subject being Christian unity. Who could know that "A Crown of Wild Olive" is a miscellaneous set of lectures, like "Time and Tide"; that "Sesame and Lilies" is a discussion of good literature; that the "Queen of the Air" studies Greek atmospheric myths; that "Ethics of the Dust" deal with crystallization; "Ariadne Florentina" with wood and metal engraving; "Deucalion" with geology; that "*Muneris Pulveris*" and "Unto This Last" are statements of the writer's views on political economy and social reconstruction, which were turned out of the *Cornhill* and *Fraser's Magazine* because the readers of those publications could not endure their supposed scientific unorthodoxy; that "Proserpina" is a study of flowers, and that "*Fors Clavigera*" — a title no one ever really understood — comprised letters to working men on every conceivable subject?

JOHN RUSKIN
From a photograph by G. P. Abrahams.

Ruskin's manner of publishing his books was as unusual as his naming of them. He issued them from a workshop privately organized, and he charged prices which he thought represented their intrinsic value. He did not wish anyone to read his books who was not prepared to make some sacrifice to get them. In spite of this rejection of the ordinary methods of business, the works continued to sell, till they brought him a handsome income, which was very convenient, because in later life he had given away nearly the whole of the fortune left him by his father,

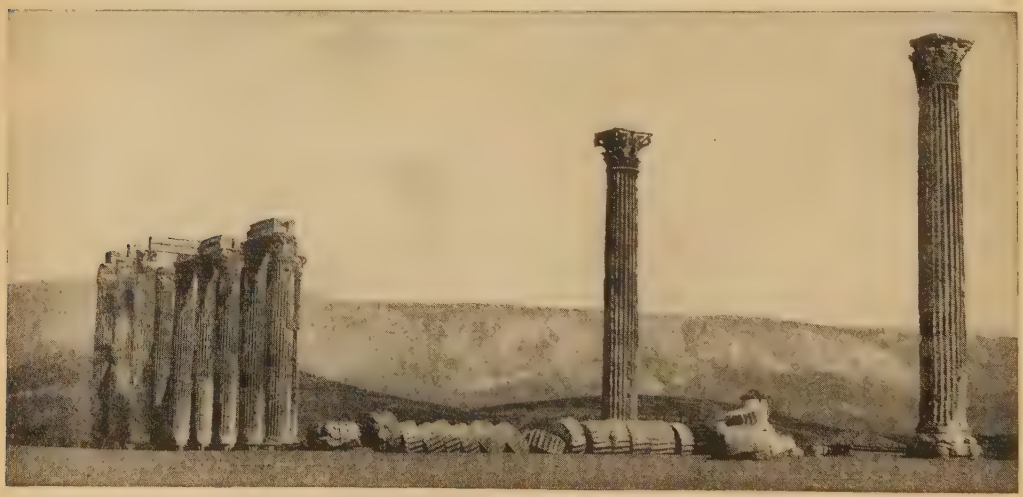
and he believed in living on capital, ordinary investments being regarded by him as examples of the usury his soul abhorred.

Ruskin, whose mind frequently failed during his later years, lived in great peace, but for recurring mental turmoil, at Brentwood, on Lake Coniston, and there he died on January 20, 1900, having refused all the honors which men of every nation were ready to offer him.

Few great writers have been so fortunate in their biographer. Long before his death, when he was asked for some explanation of one of his works, he referred his correspondent to "a young man at Oxford" who knew far more about his books than he did himself. That young man, now Sir E. T. Cook, has published the final edition of the whole of Ruskin's writings, and has written his life, with incomparable industry, taste and ability, so that once and for all this great master is placed in the story of English literature, and in the future no one need mistake either his life or writings.

In his own day Ruskin's life and writings were an incalculable stimulus. They cut right across many accepted ideas, and compelled those who wished to be thought thinkers to think. Though his attempts to organize social and industrial projects failed, and his St. George's Guild died away to a mere name, the only tangible residue of labors in this field being the beautiful little collection of choice objects of art and natural beauty gathered in the Ruskin Museum at Sheffield, Ruskin's ideas are deeply permeating thinking circles. Already they have caused some of the most dearly cherished tenets of the old economists to topple down. His preaching of a sincere life, satisfied with the great, simple things of nature, instead of insincere and ostentatious show of things that happen to be a fashion, is bound to come, sooner or later, as a balm to an age satiated with vulgar parade.

In the realm of art he remains the one great writer. He made clear the moral element that is behind all true art, and he brought art right into the consciousness of his own nation, where it had never been before. Art, which meant so much to ancient Greece and medieval Italy, may never conquer the cold North, but Ruskin unveiled it to all who have eyes to see, and added to it a generous wealth of appreciation of the beauty of the natural world, of earth and air and water, and all their lovely products, stable as in the precious stones, evanescent as in the cloud-drift, with union of use and grace, as in the grass, whose every spike is a sword-blade, and nobility, as in the solemn rest of stupendous mountains. Whether he is more and more appreciated as time runs on depends on whether the vision of the human race contracts or expands. His view of the world should long give delicacy to human culture.



RUINS OF THE TEMPLE OF OLYMPIAN ZEUS AT ATHENS

EGGS AND EGG SUBSTITUTES

An Important Item in the Dietaries
of Growing Children and Invalids

THEIR ACTUAL AND COMPARATIVE VALUE

EGGS of various kinds were doubtless one of the earliest foods and they are still a common article of diet throughout the world. The eggs of domesticated fowls are the ones which are principally used, although the eggs of wild fowl, birds, fish and some reptiles are also edible. The latter varieties, however, are so rare and so difficult to obtain that they are not of commercial importance. Since hens' eggs are so much more available than all others, statements here made may be understood to refer to them.

The production of eggs is widely distributed. They are produced on almost every farm in the United States and Canada. Generally speaking, the months of March, April, May and June are those in which the largest number of eggs are laid and it is during this time that many are put away for winter use.

Eggs are graded for the market according to freshness, size, color, cleanliness and cracks. The sorting according to size, color, cleanliness and large cracks can be done readily by the unaided eye, but where the cracks are very fine they can be detected only by clicking two eggs together (a cracked egg, tapped against an uncracked one, gives a deadened sound), or by candling. The first grading by the unassisted eye or ear is comparatively easy, but it takes experience to be able to determine the condition of an egg by "candling", that is, by holding it before a strong light and allowing the rays to come to the eye through the partially transparent shell and contents. Eggs can best be candled in a dark room by using a bright light inclosed in a box (an "egg-tester") with a hole in it slightly smaller than the egg, directly in front of which the egg is held for examination. The egg should be given a few moderately rapid twists to the left and right, thus bringing the entire surface to view. By this means the size of the air space and condition of the white and yolk may be observed. The air space of a fresh egg is less than three-quarters of an inch in diameter, but owing to the evaporation of water from

NEW LAID EGG

the liquid contents, it increases as the egg grows older. The white of a fresh egg should be firm and thick, and in candling its condition is determined by the action of the yolk. When the egg is fresh the yolk remains nearly stationary, but in an older egg the yolk moves quite rapidly. When a fresh egg is turned, the yolk is seen dimly as a dark, shadowy object which moves slowly; in a stale one, the

yolk appears plainly and moves rapidly, due to the thinness of the white. A bad egg may be readily detected from the fact that it appears dark and opaque instead of clear and transparent. Eggs suffi-

TYPICALLY STALE EGG

ciently good to pass the candling test may then again be divided into many grades, according to color, size, cleanliness, etc.

After candling, eggs are ready for the market or for preservation. Since eggs

TYPICALLY BAD EGG

are usually abundant and reasonable in price during the spring and early summer, they may be profitably preserved at that time for use during the winter when they are scarce and expensive.

Some methods of preserving eggs

Eggs may be preserved in either of the two following ways:

(1) By coating, covering or immersing the egg in some material to prevent evaporation of water from the egg contents and to prevent the entrance of organisms. This method has been in use for many years, and bran, salt, sawdust, etc., have been the materials most frequently used. After much experimenting, however, the best results have been obtained by immersing the eggs in a solution of sodium silicate, or "water-glass". This material cannot be used commercially but good results have been obtained when it is used in home preservation, if precautions are taken before starting to see that the eggs are clean, fresh, free from cracks, etc.

(2) By a low temperature, as in cold storage. The preservation of eggs by cold storage is a commercial process and enables us to have a perishable food available at all times. That egg production is much higher and prices much lower in early spring than in the fall and winter, is a fact of which dealers make use. The surplus supply of the spring months is bought up and put into storage to await the season of scarcity and increased prices. Although storage eggs even during the winter do not reach the price of fresh eggs, still the price is sufficiently above the amount paid for them to yield a profit after storage expenses have been paid. Once in a while we see an article in the press calling attention to the fact that the cold storage men are receiving large profits which rightfully belong to the farmer, and advising the farmer himself to send eggs to cold storage or preserve them in some other way. As a matter of fact such advice is unwise, for the shipping, storing, insuring and selling of the individual cases of eggs would eat up all possible profit.

The prejudice against cold storage eggs

It is a well-known fact that the majority of people have a strong prejudice against cold storage eggs, and this is due no doubt to the characteristic flavor and their behavior in cooking. In a recent investigation

carried out under the United States Department of Agriculture, it was found that fresh, clean, candled eggs stored during the spring could be kept for eleven months. At the end of that time, the white and yolk could be easily separated; the air space increased in size during the time of storage; the white turned slightly yellow: the characteristic "cold storage" taste was present after the seventh month and it became more pronounced the longer the eggs were stored. Although these changes do take place, they do not indicate decomposition. Storage eggs are less desirable than the really fresh eggs but they are wholesome and there is no reason why they should not be used, providing they have been stored under ideal conditions and not kept too long.

Frozen and dried eggs

In the commercial handling of eggs there is a great loss due to spoilage and to the waste of so-called "cracks" and "leaks". During the last few years methods have been worked out for the preservation of such eggs by freezing and drying. Freezing is used quite extensively, but the frozen product is bulky, difficult to ship and is not practicable for home use. On the other hand, the dried egg product is packed in small containers which can be easily handled and stored. The commercial drying of eggs has been investigated and is described in a bulletin published by the United States Department of Agriculture. The egg-breaking season is from April until October, principally June, July and August. The eggs are graded by candling and those to be used in drying are broken on a specially prepared knife-blade or in some cases on the side of a metal cup. The eggs are mixed, strained, mixed again and are then ready for drying either by the instantaneous or belt method. In the instantaneous method the eggs are sprayed into a heated chamber at a temperature of about 158° F. where they are at once turned into a fine powder. In the belt method the egg mixture is dried on an endless belt of zinc or galvanized iron. The temperature of the heated chamber is kept at about 140° F. and a thin film of egg is dried in one revolution. After several layers have been dried, they are removed and further dried for two or three hours at a temperature of from 98° to 104° F. Either method gives a satisfactory, sanitary product.

It is of interest to compare the price of dried egg powder with that of fresh eggs. One egg of average size weighs two ounces, and allowing 11 per cent for the shell, the edible contents of a dozen eggs would weigh about twenty-one ounces. Since the edible portion contains about 73 per cent water and dried egg powder only about 5 per cent, one dozen eggs dried should yield at least five and a half ounces of dry material. The contents of one sample of dried egg powder which the manufacturer claimed to be equal to one dozen eggs was found, taking an average of several packages, to weigh three and a half ounces and was therefore equal to only seven and two-thirds eggs of average size. The tin of dried egg powder cost forty cents so that one was actually paying at the rate of sixty-two and a half cents a dozen for eggs of average size when first-grade cold storage eggs were selling at sixty cents a dozen. This same brand of dried egg powder was investigated somewhat thoroughly in connection with the preparation of food and it was not found to be entirely satisfactory in straight egg dishes such as scrambled eggs; neither did it greatly improve the flavor or texture of mixtures such as cakes or muffins. Moreover, the egg powder was somewhat difficult to use and the average housewife would be apt to waste material in learning to get satisfactory results. This waste would increase the initial cost. The dried egg powder has the advantage that it will keep for some time, as long as it is cool and dry, and it is therefore possible to have it always on hand. Investigations indicate that the food value of the egg is not appreciably impaired by the process of drying.

The composition and food value of eggs

The average percentage composition of an egg as purchased is given in Bulletin 28 of the United States Department of Agriculture as:

Shell	11.2 per cent
Water	65.5 "
Protein	11.9 "
Fat	9.3 "
Mineral matter	0.9 "

The percentage composition of the edible portion is:

Water	72–75 per cent
Protein	12–14 "
Fat	10–12 "
Mineral matter	1 "

These percentages show that eggs have a high water content and are also rich in protein and fat but contain no carbohydrate. When we consider that a fertile egg, if kept at proper temperature for about three weeks, produces a chick which begins at once to walk and to eat much the same kind of food as the adult, it must be acknowledged that the egg contains substances which are very efficient both as sources of energy as well as for growth and development. In other words, it contains protein and mineral matter as building materials and fat as a concentrated energy food for the developing chick.

In our foods are found many different varieties of protein, but feeding experiments have shown that some are more capable than others of providing normal growth in children and maintaining health in adults. The proteins of egg are of the best type. The protein of the egg white is called "egg albumin", but instead of being merely one substance it is made up of four proteins of the albumin group. Ovovitellin is the chief protein of egg yolk, and it is believed to exist in a chemical combination with the fat and phosphorus. The fat of egg is practically all in the yolk and is in a finely emulsified condition, which makes it very easy to digest.

The mineral constituents of the egg, in conjunction with the protein, are well adapted to the formation of body tissue; and eggs are particularly rich in most substances which enter into the construction of bone, blood and muscle. They have a fair amount of calcium, a good proportion of phosphorus and are particularly rich in iron. When eggs are compared with milk, it is found that they are very much poorer in calcium though they contain a much larger proportion of iron. The iron is in a form which is readily made use of by the body. Although eggs are rich in certain mineral constituents it would be wrong to believe that one could obtain the total daily requirement of minerals from eggs alone. From experiments it has been found that a man of average size requires daily about 0.68 grams of calcium, 1.32 grams of phosphorus and 15 milligrams of iron. But one egg gives only 0.034 grams of calcium, 0.092 grams of phosphorus and 1.5 milligrams of iron. Therefore, while ten eggs would supply the iron requirement, it would take fourteen to supply the phosphorus and twenty to supply the calcium for the day.

In addition to the protein, fat and mineral matter, there are found in eggs those substances so essential for proper growth and development, namely, the vitamins. Vitamin A is the most important one found in eggs. Investigations have shown that the amount present depends upon the food which the hen receives. When given food rich in vitamin A the eggs were found to be rich in this vitamin; when given food deficient in vitamin A the amount of this vitamin in the egg was greatly lessened. Thus we see the necessity of properly feeding poultry in order that the eggs may contain the greatest amount of nutritive factors.

The economic value of eggs

It is a well-known fact that the price of eggs is not determined by their chemical composition or their food value. Investigation shows that eggs vary greatly in size (see figure on page 4763). For instance, from one dozen, as purchased, the smallest egg weighed 1.6 ounces and would yield 62 calories; a medium-sized egg weighed 2 ounces and would yield 75 calories; the largest egg weighed 2.3 ounces and would yield 88 calories. Calculating the cost at 40 cents a dozen, it was found on this basis that one pound or 10 small eggs would cost 33.3 cents, one pound or 8 medium-sized eggs would cost 26.6 cents, one pound or 7 large eggs

would cost 23.3 cents. Thus we find that at the same price a dozen, one pound of small eggs would cost almost half as much again as one pound of large eggs although the food value as expressed by the number of calories is practically the same. Regardless of size, eggs are often sold by the dozen but this comparison indicates that it would be fairer to buy them by the pound.

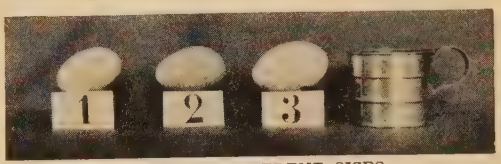
The use of eggs in cookery

Eggs may be served alone or in combination with other food materials, and when cooked in different ways there are marked changes in the appearance and physical properties of the egg, and in the ease of digestion.

If an egg is boiled for two minutes, the white nearest to the shell will generally be coagulated, while the rest of the white will be milky, and the yolk, though warm, will be as fluid as in the raw condition; if boiled for three minutes, the white will be coagulated and the yolk a little thickened; if boiled for ten minutes it is termed "hard-boiled". All of these changes are due to the coagulation and hardening of the protein by heat. The method of placing an egg in boiling water and boiling for three or four minutes is not to be recommended. A better product is obtained if the egg is placed in a vessel of boiling water, covered and immediately removed from the fire. By this means the temperature will still be sufficiently high to coagulate the protein and yet not toughen it. A cup of water should be allowed for each egg and the eggs will be "soft-boiled" in five or six minutes; "hard-boiled" in thirty or forty minutes. Uniform results cannot be expected when conditions vary. The time of cooking, the amount of water used, the number, temperature and freshness of eggs and the kind of vessel used are important factors.

In poaching, eggs are removed from the shell, placed in boiling water and should then be immediately removed from the fire and left until suitably cooked. If a little vinegar is added to the water it will help coagulate the egg white. Fried eggs, which are usually cooked in a flat pan, in a little hot fat, are not as easily digested as those cooked in other ways, as the coagulated protein becomes coated with fat and as a result is not so readily acted upon by the digestive juices. In view of this fact, why not serve poached instead of fried eggs with bacon? The dish will be just as palatable and more easily digested.

In all dishes where eggs are combined with other materials, they give consistency, color, flavor or lightness. In cake, etc., they are used to improve the flavor and texture and to help lighten the mixture; while in custards, etc., they thicken and give the desired consistency. Well-beaten egg white is also used to aërate many forms of cakes and desserts. The beaten white incloses the air in tiny bubbles which become distributed through the mixture on mixing and expand on heating. The heat of cooking also coagulates the protein, thus enabling the mixture to retain its shape.



EGGS OF DIFFERENT SIZES

1. Egg weighing 1.6 oz.
2. Egg weighing 2 oz.
3. Egg weighing 2.3 oz.

The mug is a standard half pint.

The shrinkage of sponge cakes, foamy omelets, meringues, etc., is due to improper coagulation. Too great or too long continued heat causes the toughening of these mixtures. Egg yolk may lighten a mixture to a very slight degree, but owing to the large amount of fat in it, it cannot retain very much air. It is of greater value as a thickening agent. When kept at the temperature of boiling water, or even a lower temperature, for a considerable time, the proteins of egg become hard and contract. This explains the curdling of custards.

The digestibility of eggs

"The term 'digestibility' refers to the thoroughness of digestion, that is, to the total amount of material which any food gives up to the body in its passage through the digestive tract." Only soluble or emulsified material can be taken into the circulation to nourish the body, and there-

fore only those materials which are acted upon and broken down by the digestive juices can be fully digested. The original condition of the food, the method of cooking and the amounts eaten at one time are some of the factors which influence the amount of any food which can be digested. Experiments have shown that about 97 to 98 per cent of the protein content of egg is digested and practically 95 per cent of the fat. Eggs cooked below the boiling temperature — "soft-cooked" — were found to be most readily and rapidly digested; but whether the egg was cooked *below* the boiling temperature or *at* the boiling temperature did not seem to influence the ultimate amount digested, namely — eggs "soft-cooked" were digested in a short time; boiled, in a much longer time; but in the end both were digested and absorbed to the same degree. For many years it has been thought that raw eggs were more easily and completely digested than those which were cooked. During the last few years investigators have found that while raw eggs pass more rapidly through the stomach, very little digestion takes place until they reach the intestines. When the eggs are slightly coagulated by heat, more thorough and rapid digestion takes place. The same holds true of beaten egg white which is used for meringue, etc. If the egg white is not to be browned in the oven, it may be cooked by placing large spoonfuls on a pan of hot water. This method will not destroy either the appearance or flavor.

A comparison of the protein content in typical egg dishes

All of our foods contain some or all of the five food principles, — protein, carbohydrate, fat, mineral constituents and water, in varying amounts. If a food contains sufficient protein to supply 20 per cent of the total calories, it is considered to be high in protein. Eggs yield 36 per cent of the calories from protein and are therefore "protein-rich". Many of the common dishes prepared in the home contain eggs and for this reason are thought to be high in protein, but when the total calories and percentage of calories from protein are worked out it is found that in many cases the protein is just balanced or is below par. This lowering of the percentage of protein is due to the large amounts of other materials rich in carbohydrate or fat which have been added. When poached egg on toast is prepared, using a 100-Calorie portion of bread and a 25-Calorie portion of butter and one egg, the protein supplies 20 per cent of the total calories, and the dish may therefore be regarded as protein-rich. Using standard recipes for sponge cake and tapioca custard, on account of the relatively large amount of sugar added, the protein supplies only about 12 per cent of the total calories. Baked custard, and bacon and eggs are generally thought of as high protein dishes, but as usually served the protein supplies not more than 15 per cent of the total calories.

The value of egg substitutes compared with eggs

A few years ago egg-substitute powders were unknown, but with the increased cost of living and the rise in price of eggs, manufacturers have put on the market a number of these powders said to be the equivalent of eggs at a much lower cost.

In the preparation of foods, eggs are used either to lighten, as in cakes, or to thicken, as in custards; and the aim of the manufacturer has seemed to be to produce a substitute that would do either or both of these things, but in the majority of cases no consideration has been given to the chief importance of egg, namely, its food value.

There are two distinct types of egg-substitute powders — those containing some dried egg and those without egg. The former are a mixture of dried egg and starch, while the latter may be made of starch and a protein, or starch and the ingredients of baking powder.

In one sample which contained some egg the manufacturer frankly stated that it was not *all* egg, but he did claim that one can of the product was the equivalent of two dozen eggs. If even one dozen eggs of average size had been dried, there should have been about five and a half ounces of dry material (see page 4761), but

the contents of the can weighed less than four ounces. Government analysis showed the composition to be about 50 per cent egg and 50 per cent cornstarch with a little coloring matter, so in reality the can of egg-substitute powder contained the dried material from about four and one-half eggs and two ounces of cornstarch; and cornstarch is a pure carbohydrate with no protein, mineral matter or vitamins. Two ounces of cornstarch and four and one-half eggs would yield approximately 550 Calories while two dozen eggs would yield about 1800. Therefore, from the standpoint of calories the purchaser obtained only about one-third of the value that the manufacturer claimed for the product. From the standpoint of mineral constituents and vitamins the comparison would be even less favorable.

Investigations were also made on powders containing no egg. In those containing starch and protein, the starch was generally found to be from corn, and government analysis showed the protein to be from skimmed milk, gelatin or cereals. The proteins in skimmed milk and in eggs are both classed as grade A, while the proteins of gelatin and cereals are inferior in quality. Further, these egg-substitute powders contained a very small proportion of protein. Besides this deficiency the so-called substitutes contained no vitamin A or appreciable amounts of iron and the cost was out of proportion to the value received.

In the last class, namely, those composed of starch and baking powder, the starch was either cornstarch or rice flour together with baking soda, an acid phosphate, and some coloring matter; and the action of the product in a flour mixture was merely that of a baking powder. The contents of one can weighed about 6 ounces and cost 20 cents, making the price about 53 cents a pound. A good grade of baking powder can be purchased for less.

From these considerations one can readily see that egg substitutes are not an economy either in food value or cost.

In conclusion, the food value of eggs may be briefly summarized: they are a good source of grade A protein; supply fat in a form which is easily utilized by the body; are rich in iron, in phosphorus and in vitamin A. Eggs thus rank as an important food and this fact should be considered, especially in planning dietaries for growing children and invalids.

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WHITE LEGHORNS

A CIRCLING ZONE POWDERED WITH STARS

THE PATH OF THE MILKY WAY THROUGH THE HEAVENS, SHOWING THE NEIGHBORING STARS

The Milky Way, when seen from the earth, appears as a great ring of stars. These two drawings show the two semi-circles of the Milky Way as they extend from the region of the Polar Star to the region of the Southern Cross on each side of the apparent sphere of the heavens. It will be noticed that the bright stars congregate near its region, and that there is a characteristic harmony in the way in which the wisps appear to project into space, suggesting some common cause for this appearance throughout the whole galaxy.

THE WONDERFUL MILKY WAY

Unsolved Problems of Starland. Sounding the Vast Depths of the Sidereal Universe

WHAT IS THE UNREAD PLAN OF THE HEAVENS?

EVERYONE knows the Milky Way. It is one of the most striking sights of a clear night, for only on clear, moonless nights can we see the outlines of its cloudy track of light across the heavens. More than any other celestial object it affects us with a sense of mystery and of unknown destiny — as, indeed, it has affected men at all times and in all countries. To the redman it was the "path of souls". In ancient mythology it had various meanings: thus, it was the highway of the gods to Olympus; or it sprang from the ears of corn dropped by Isis as she fled from her pursuer; or it marked the original course of the sun, which he later abandoned.

In medieval times it became associated by pilgrims with their own journeys. Thus, in Germany, it was the "Jakobstrasse", or the road to the shrine of St. James at Compostella; in England, it was the "Walsingham Way", associated with the pilgrimages to the famous Norfolk shrine of that name. There was nothing absurd or trivial in fancies of this kind; the pilgrim had no idea that his travels were the end and purpose of the Milky Way. He merely found it lying overhead, a mysterious path in the heavens; and his sense of universal unity led him in a childlike way to feel a deep association with it, and a sense of its intimate companionship. But this friendliness of the heavenly bodies, and the simple affection for them which we find in Chaucer and other medieval poets, have been destroyed for most of us by the mere interposition of unimaginable distances.

The best times for seeing the Milky Way are in the evenings of autumn and winter; it is then high in the heavens, and thus suffers less from the interference of our atmosphere. It is then seen to stretch like a vast, ragged semicircle over the sky. Indeed, it traces a rough circle, for this line is continued over the southern hemisphere also. The circle is, however, very far from being smooth or even; the path is full of irregularities. Its average width is about twenty degrees, but it varies considerably both in width and in brightness. Its total area has been estimated to cover rather less than one-fourth of the whole northern hemisphere of the sky, and to cover about one-third of the southern hemisphere. Its track lies through the constellations Cassiopeia, Perseus and Auriga; it passes between the feet of Gemini and the horns of Taurus, through Orion just above the giant's club, and through the neck and shoulder of Monoceros, here entering the southern hemisphere. It passes above Sirius into Argo and through Argo and the Southern Cross into Centaurus. Here it divides into two streams separated by a dark rift, in a manner which suggests the divided course of a river, around an island.

It is a very long island, however, for the double conformation of the Milky Way extends over one-third of its entire course — that is to say, one hundred and twenty degrees of the circle. The divergent branches reunite in the northern hemisphere in the constellation Cygnus. The brighter stream passes through Norma, Ara, Scorpio and Sagittarius; along the bow of Sagittarius into Antinous, here

entering the northern hemisphere again; then through Aquila, Sagitta and Vulpecula it arrives at Cygnus and reunites with the branch which left it in Centaur. From Cygnus the stream, now single, passes through Lacerta and the head of Cepheus to the point whence we started, in Cassiopeia.

As we follow the Milky Way throughout its course, we find it continually sending out streaming appendages of nebulous appearance towards clusters, nebulæ, or groups of stars. In Norma it sends out a complicated series of nebulous streaks and patches, covering the Scorpion's tail, spreading faintly over the leg of Ophiuchus, and extending beyond, as if to meet a corresponding branch sent off from the region of Cygnus in the northern hemisphere. The latter is a very bright and remarkable streak, running south through Cygnus and Aquila, to become lost in a dim and sparsely starred region. From Cassiopeia a vivid branch proceeds to the chief star of Perseus, and faint streaks appear to continue the "feeler" towards the Hyades and the Pleiades. There are many other feelers of the same kind, and they are all of great interest, because they seem to show some sort of influence exercised by the Milky Way upon the whole sidereal universe.

Proofs of the dominating position held by the Milky Way

But there are other indications, also, that the Galaxy holds a dominating position. For example, the Milky Way seems to determine very directly the groupings of various bodies in the heavens. The regions through which it passes are the exclusive habitat of certain classes, while other classes as consistently avoid it. Thus the gaseous nebulæ are almost all in or close to the path of the Milky Way, but the "white" or spiral nebulæ, on the contrary, congregate at a distance from it. Globular clusters, again, are found in very large numbers within it; in fact, a continuous line of star-clusters lies along its center for a considerable part of its course, forty out of about a hundred known clusters being within this zone. The open star-clusters, of which there are several hundred, are also in or near the galactic plane. This marked preference of clusters for the region of the Milky Way is worthy of notice, because of the suggested relation between globular clusters and the spiral nebulæ, which avoid that region. Red stars, gaseous stars, and short-period variables display also a preference for the region of the Galaxy.

Ancient and modern conceptions of the nature of the Milky Way

Strange theories as to the nature of the Milky Way have been advanced at various times. Anaxagoras thought it might be due to the shadow of our globe; Aristotle, that it was some kind of mist due to the exhalation of vapors from the earth.

But a grander and truer conception of its nature and situation, removed far from the earth and independent of any terrestrial cause, had early come to several minds. Pythagoras and Democritus both formed the conjecture that its shimmer might be due to innumerable stars, and in 1610 Galileo's telescope confirmed their theory.

As we have seen, the Milky Way is by no means a simple stream of stars; with careful observation, even the naked eye can perceive something of its irregular detail, when the atmosphere is unusually clear and there is no moon. Viewed under these conditions through a good telescope, the effect of the Milky Way, when made to pass progressively before the vision, is one of unexampled grandeur and sublimity.

The general effect has been well likened to that of an old, gnarled tree-trunk, marked with knots and curving lines, and riddled with dark holes and passages, linked together by shimmering wisps or arches. This general effect is practically lost as the detail becomes clear in a telescopic view. The detail is extremely various. At one point it may consist of separate stars scattered irregularly upon a background of darkness; at another, of star-clusters, sometimes following one upon another in long, processional line; at another, the stars seem to collect in small, soft clouds, presenting the appearance, as the telescope sweeps over them, of drifting foam.

The strange, dark rifts in the skyscape where no stars appear

At yet another point the track may be involved in nebulosity in which many stars appear to be imbedded. Perhaps the most characteristic features are several which have already been remarked as conspicuous in star-clusters or nebulæ, such as lines of stars, dark lanes having the appearance of rifts, and more extended areas devoid of all light. The lines of stars, which are evidently connected by some actual physical relation, are either straight, curved, radiated or in parallels. In Sagittarius is a very striking collection of about thirty stars resembling in form a forked twig with a curved hook at the unforked end. The dark rifts in the Milky Way show the same features as those in star-clusters. Sometimes they are parallel; sometimes they radiate like branches from a common center; sometimes they are lined with bright stars; sometimes they are quite black, as if utterly void; sometimes slightly luminous, as if powdered with small stars.

Large, dark areas, resembling the Keyhole and other similar formations in nebulæ, are very frequent. The most famous of these is the Coal-sack, which occurs close to the constellation of the Southern Cross. Soon after the southern reunion of its two branches in Centaurus, the Milky Way broadens and appears studded with a collection of brilliant stars, so that this is one of the most resplendent areas in its whole course. Right in the center of this host of bright stars, and close to the four chief stars forming the Cross, is what appears to be a pear-shaped cavern blackly dark. This apparent opening into the great void is known as the Coal-sack. Many attempts have been made to explain away this phenomenon as an optical effect, but all these attempts seem quite inadequate. The sharp distinction of its outlines, its huge size, its utter darkness, and the even brightness of the starry edge surrounding it, make it almost certain that we have here a mass of obscuring matter cutting off the light of the stars behind it. It is by no means unique; there are a great many similar black areas, generally less clearly defined and less striking in appearance, but manifestly of similar nature. Barnard describes one of these, in Sagittarius, as "a most remarkable, small, inky-black hole in a crowded part of the Milky Way, about two minutes in diameter, slightly triangular, with a bright orange star on its north preceding (northwesterly) border, and a beautiful little cluster following". Here, again, a dark vacuity is found in conjunction with a number of bright stars.

Has some disintegrating force been at work in expanses of the heavens?

Another very striking irregularity is the Great Break in Argo, which occurs shortly after the Coal-sack. After its expansion in the Southern Cross the stream of the Milky Way narrows, but spreads out fanwise in Argo; and here, at its widest part, it is cut sheer across by a dark irregular break. On either side of this Great Break the stream sends out finger-like branches of faint light, as if attempting to reach across, the branches on opposite sides of the Break being in obvious correlation. The appearance of a once-united stream rent asunder by some great force or by the intrusion of some foreign non-luminous body is very strongly suggested by this chasm; and, unless the apparent break is really due to intervening opaque matter, these dark rifts and chasms of the Milky Way, like those of star-clusters, point to the presence within this vast structure of some disintegrating force, which may eventually result in its entire dissolution.

The nebulous wisps and feelers which the Galaxy throws out towards stars, constellations or nebulæ are very interesting. Tenuous feelers of this kind reach, or very nearly reach, among others, the Hyades, the Pleiades, Præsepe, Orion's left shoulder and the Pole Star.

But a still more interesting fact has been discovered with regard to the relation of the Milky Way with all the other stars of the heavens. It is that, on the whole, the stars tend to increase in number gradually and in regular order toward the region of the Milky Way. According to Sir William

Herschel, the distribution of fairly bright stars is thirty times more dense in the galactic plane than at its poles. This law of galactic crowding has been traced further in remarkable detail by later investigators, and it has been found that a similar, though not numerically equal, crowding marks the distribution of the fainter stars also.

Is there a meaning in the crowding together of the most brilliant stars

This crowding is well exemplified, for instance, in the positions of the ten most brilliant northern stars. Three of these — Capella (in Auriga), Altair (in Aquila) and Deneb (in Cygnus) — stand almost upon the central line of the Milky Way; while four more — Vega (in Lyra), Procyon (the lesser Dog-Star), Betelgeux (in Orion) and Aldebaran (in Taurus) — are either just within or upon its borders. Only two out of the ten — Regulus and Arcturus — are at any considerable distance from the Milky Way. Yet, in proportion as the stars diminish in brilliance, their crowding toward the galactic zones becomes, for the stars visible to the naked eye, less and less marked, until it can barely be perceived in the case of those which are only just perceptible by unaided vision. In the first ranks of telescopic stars — that is to say, about the seventh magnitude — there is hardly any of this crowding, but in magnitudes below this it is again progressively evident.

Evidence of a general plan of construction in the heavens

This regular and conspicuous law is almost conclusive evidence of a general plan of construction in the heavens, in which the Milky Way is intimately involved and in some way dominant. A further proof of this dominance is supplied by the grouping of the nebulæ in the sky, for they form a striking contrast, or complement, to the grouping of the stars.

Two great zones in which spiral nebulæ are condensed are clearly apparent, and a map (see page 1553), showing both these areas and the path of the Milky Way, is very instructive. A large zone, with the Milky Way as its central line, is almost clear of nebulæ, which congregate as two great canopies hanging about the galactic poles. This accumulation of nebulæ towards the pole is particularly marked in the northern hemisphere; in the southern hemisphere, although the same principle prevails, there is less concentration, and the nebulæ appear more evenly dotted over the sky. The wide zone, which is avoided by spiral nebulæ, about the entire circle of the Milky Way, is very pronounced. Over gaseous nebulæ, on the contrary, the Milky Way exercises not a repellent but an attractive influence, just as it does over stars and star-clusters.

The curious avoidance of each other by stars and nebulæ

The study of the Milky Way emphasizes very strongly the "relation of avoidance" between stars and nebulæ. The apparent law, already well known to astronomers a century ago, was thus summed up by Herbert Spencer: "In that zone of celestial space where stars are excessively abundant, nebulæ are rare; while in the two opposite celestial spaces that are furthest removed from this zone, nebulæ are abundant. Scarcely any nebulæ lie near the galactic circle; and the great mass of them lie around the galactic poles. Can this be mere coincidence? When to the fact that the general mass of nebulæ are antithetical in position to the general mass of stars we add the fact that local regions of nebulæ are regions where stars are scarce, and the further fact that single nebulæ are habitually found in comparatively starless spots, does not the proof of a physical connection become overwhelming?"

The sublime constructive scheme that baffles human research

It is impossible to contemplate the vast system of the Milky Way, and the incontrovertible evidences of its intimate and far-reaching connection with the distribution of the heavenly bodies outside its own system, without speculating as to the nature of these relations, and as to their possible indication of some vast scheme of construction in the entire heavens. The

knowledge of stellar varieties, of the giants and dwarfs, of the violet-white Sirian and of solar stars and of all the other kinds, and our knowledge of the marvelous movements, variations and systemic relations of stars, expand and deepen the glory and mystery of the heavens. The sense of some vast, undiscovered plan comprehending the movements and relations of all is altogether in keeping with the sublimity with which the night sky impresses everyone. But when we review the attempts to construct this scheme we are baffled by a sense of their inadequacy and artificiality.

Rejected guesses at the architecture of the celestial temple

Sir William Herschel's "disc theory" was for many years generally accepted as a credible explanation of the distribution of the stars in the heavens. This theory had already been put forward, thirty years earlier, in 1750, by Thomas Wright, of Durham, but Herschel adopted and strengthened it by applying to it his method of "star-gaging". Starting from the hypothesis that the stars are actually, on a broad average, evenly distributed so that the distance between any two neighboring stars is the same throughout the space occupied by the system, he ascribed the appearances of concentration and of wide scattering to the varying depth or extent of the system as viewed from the earth; and was thus led to conceive of the heavens as a vast system of stars evenly distributed in a form roughly resembling a grindstone, the solar system being situated near the center, and the Milky Way representing an enormous depth of stars included in our view along the plane of the disc. The actual figure which Herschel deduced from his laborious plumbing of the star-depths was an irregular disc, cloven at one end, the cleavage representing the bifurcated part of the Milky Way.

But this theory requires quite incredible assumptions in order to explain such appearances as the Coal-sack and other features of the Milky Way. The Coal-sack and other black holes could only be explained by imagining vast conical tunnels through the whole stratum of stars, all converging directly upon the solar system, while stellar groups of exceptional richness would require for their explanation as optical effects the assumption of columns of stars of tremendous length stretching out from the edge of the disc away into space. Explanations of this kind are too fanciful. It is more satisfactory to accept the appearances as corresponding to reality, and to reject the hypothesis of the even distribution of all the stars.

Indeed, Herschel himself came later to this conclusion, and rejected his own theory of a uniform disc-like sidereal system. The result of his star-gaging labors was eventually to demonstrate real inequalities of distribution. In 1802 he was able to say that "the Milky Way is by no means uniform. The stars of which it is composed are very unequally scattered, and show evident marks of clustering together into many separate allotments". Yet, notwithstanding this repudiation, the uniform-disc theory was for years afterwards accepted with all the authority of Herschel's name.

Sir John Herschel's theory little more adequate than his father's

Sir John Herschel, who continued to gage the star-depths in his father's manner, realized that the Milky Way must be a definite structure, and not a mere effect of perspective due to our position among the heavenly bodies. But he still conceived that the situation of our solar system was the most important factor in producing the appearances under which we see the Galaxy. He cut away, as it were, the center from the disc, and left the Milky Way as a flattened ring which we see edgewise from our position within its hollowed center. But this theory leaves almost all the difficulties intact. Appearances such as the Coal-sack and the Great Break in Argo require a similarly elaborate and artificial hypothesis to explain them under the conception of a ring as under that of a disc, if the ring be held to consist of evenly distributed stars seen in various positions and groupings, and looking thick simply because we regard the ring edgewise.

Any theory which regards the Milky Way as entirely or even chiefly an optical effect has to meet an insuperable difficulty in the definite outlines of the stream itself — at least over the larger part of its course. If the concentration of stars were an optical effect, it would almost inevitably be much more gradual, so that there would be no sharp limit to the Milky Way. But its outline is so well defined that in some parts one photographic plate may show one half within its borders and the other clearly without, thus including two regions of contrasted character.

A STAR-CLOUD IN SAGITTARIUS, WITH A DARK ABYSS WITHIN IT, CONTAINING BUT A SINGLE STAR
From a photograph by E. E. Barnard.

The wide prevalence of the principle of spirality throughout the whole range of heavenly bodies has led to various recent theories, which trace in the general conformation of the Milky Way double or quadruple spiral branches, so disposed to our view as to produce the effect of the stream which we have traced. About the middle of the last century a theory of this kind was brought forward by Stephen Alexander, of Princeton, who traced the origin of the celestial universe back to a great spheroidal mass subject to forces producing in it a spiral configuration, and saw in the Milky Way the surviving streams which issued from it, and flowed in four winding currents. The idea of the whole known universe as having originally been a single vast spheroid has been discredited by more recent discoveries of the extent and complexity of the sidereal system, but the theory that the Galaxy is itself a spiral structure similar to so many others which are revealed to us by modern instruments still finds many eminent astronomers to support it. And when to their characteristic structure we add the occurrence in the spiral nebulæ of clearly marked masses of occulting matter, the difficulties which the Coal-sack, the Great Break and other remarkable features of the Milky Way present to any other theory are very much lessened, if not entirely removed. Similar features characterize many of the great nebulæ, such as the black cavern of the Keyhole, the dark rifts of the Trifid nebula, and the lines or groups of bright stars, or single stars, significantly placed in relation to these dark areas. It is possible, however, to be too confident in attributing the appearance of the Milky Way to a vast spiral structure, because with increasing knowledge this starry stream may perhaps be explained on some other principle.

In the meantime our knowledge of it is so incomplete that it is safest to regard the Milky Way as closely corresponding in structure with the appearance under which we see it. That is to say, it is probably a huge, irregular collection, somewhat in the shape of a watch or a grindstone, including within its vast system an endless variety of bodies and separate systems of stars, clusters and nebulæ, and throwing out branches and "feelers" in all directions,

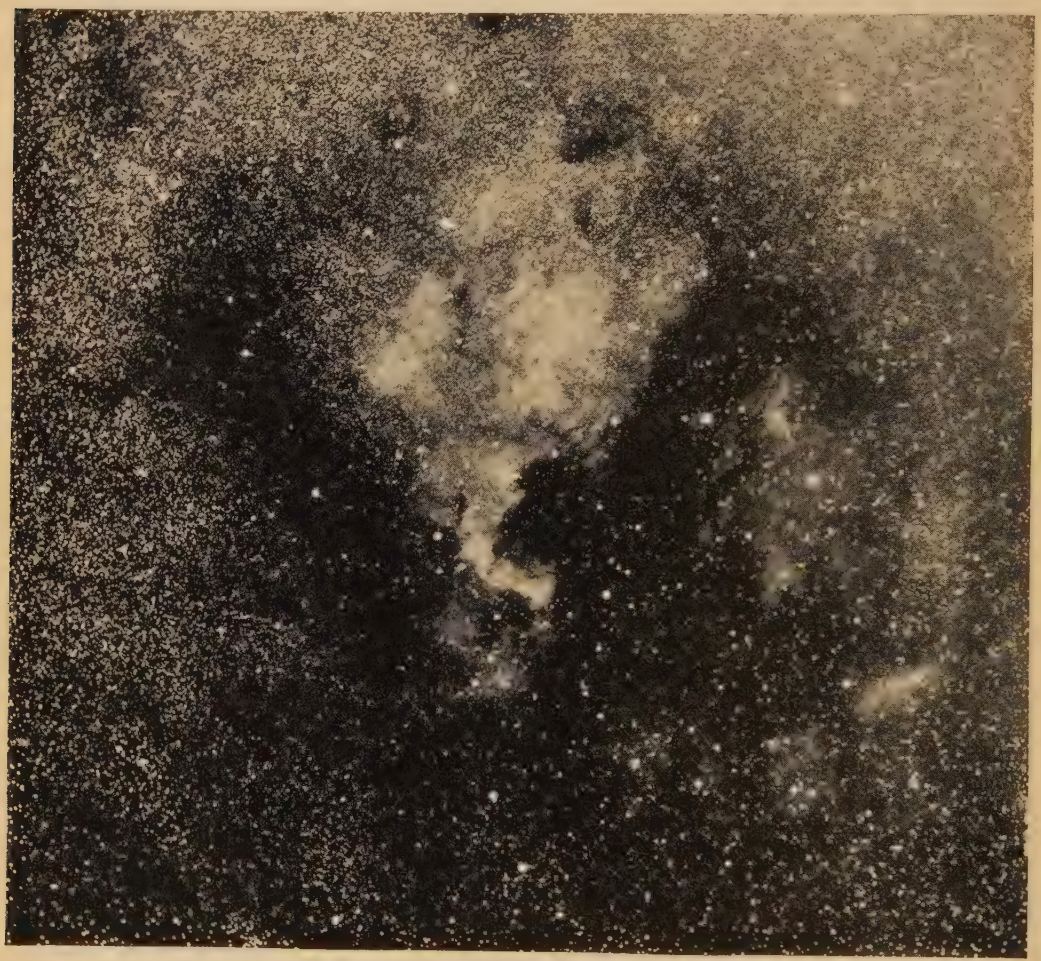
over enormous distances, and controlling in some way the distribution of the various subordinate systems contained within it or associated with it. This influence of the Milky Way seems to be predominantly attractive for large aggregates of fairly dense matter, as in the case of the star-clusters, and predominantly repellent for masses of matter of low density or wide diffusion, as in the case of the spiral nebulæ; but any very detailed conjectures with regard to the nature of this varying influence are as yet premature. Progress in the study of the problem has been considerably hampered by the great difficulty in securing any definite knowledge of the dimensions of the sidereal universe and of the distances from us of the various parts of its complex structure.

THE MAGNIFICENT STAR-CLUSTER MESSIER 13 IN HERCULES
From a photograph taken at the Lick Observatory.

Any attempt at making direct measurements of the distance from us of the star-clouds in the Milky Way results simply in showing that these clouds are immeasurably far away; none of the stars contained in them shows any perceptible parallax whatever and hence indirect methods must be followed in estimating their distance. The earlier estimates, made about half a century ago, aimed at establishing with some degree at least of probability the upper and lower limits of distance between which the clouds of the Galaxy must be: these estimates were based on an examination of the relative number of stars contained in the successive stellar groups differing from each other by one magnitude of brightness. If we assume magnitude to be, over a sufficiently wide average, a safe criterion of distance, we should expect to find the stars of each magnitude progressively more numerous than the stars of the next brighter magnitude. For as distance increases, with consequent diminution of brightness, so also does the available space increase; for the spaces at successive distances are contained within larger and larger spherical shells, with our own solar system as center. If, then, on a broad average, the stars are equally numerous at all distances, we should expect the number of stars of each magnitude to bear a regular ratio to the number of stars of the magnitude before it; and this ratio ought to be 3.98, or very closely four to one; that is, the number of stars of the seventh magnitude ought to be four times more numerous than those of the sixth magnitude, and so on. Now, from counts made of the stars listed in Argelander's great catalogue, known as the *Durchmusterung* and containing practically all the stars down to the ninth magnitude and most of those of the tenth magnitude also, it was found that from the first to the ninth magnitude the number of stars increased in fact in the given ratio, or rather in a ratio slightly inferior to it but sufficiently close to it to exclude the idea of any such addition of numbers as would result from the presence, within the sphere marked by the ninth magnitude, of the

host of stars contained in the Milky Way. It was concluded therefore that the stars forming the Milky Way do not occur within the distance of the average ninth-magnitude stars. This apparently gives us a lower limit to the possible distance of the main star clouds of the Galaxy.

The higher limit could not then be determined even with this broad degree of approximation, but yet from a consideration of Herschel's surveys which showed that the stars of the fourteenth magnitude were rather sparsely represented, it was concluded that the bulk of the galactic stars were situated at a lesser distance than that marked by the average fourteenth-magnitude star. Later counts made by Kapteyn, by Chapman and Melotte and by others, based on more complete catalogues and charts giving stars down to about the eighteenth magnitude, show that the ratio of the number of stars of successive magnitudes is, for all magnitudes, somewhat less than the theoretical value of 3.98 required on the supposition of equal distribution of stars at all distances from us, and moreover that this ratio falls off rather rapidly in the case of the fainter stars, being less than fifty per cent of the theoretical value for stars below the seventeenth magnitude.



NORTH AMERICA NEBULÆ
Photographed with the 10-inch Bruce telescope of the Yerkes Observatory by E. E. Barnard.

The fact of this thinning out of the stars below a certain magnitude, so clearly exhibited both by Herschel's soundings and by all the subsequent surveys, is of great interest and affords a very striking obser-

vational confirmation of the opinion that the sidereal universe though stupendously vast is not infinite but finite and limited.

BEAUTIFUL WISP OF NEBULOUS MATTER IN CYGNUS
From a photograph taken at the Yerkes Observatory.

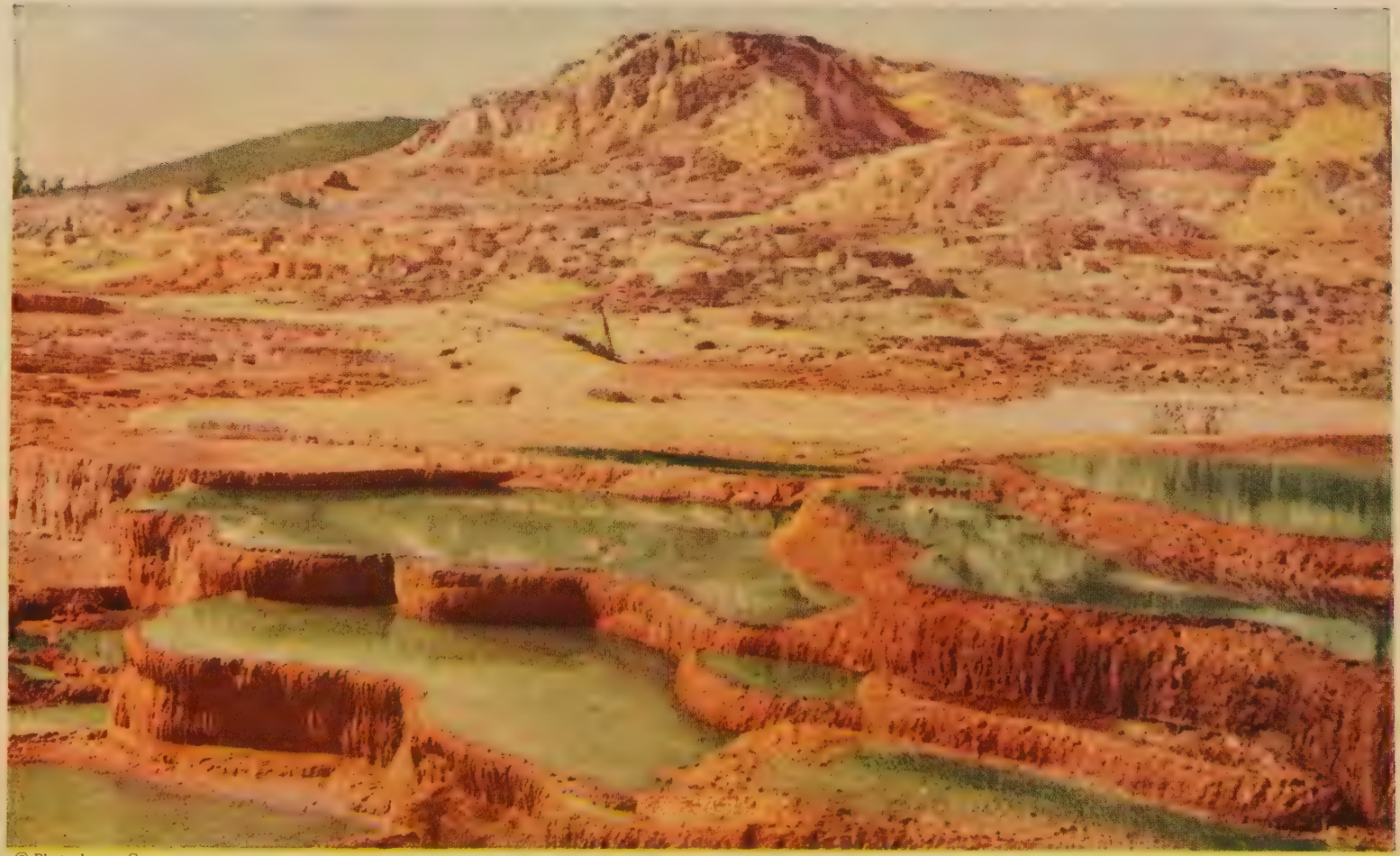
This conclusion is generally based on the argument that from an infinite universe of stars we should receive also an infinite amount of light, the increase in numbers making up at each successive step in remoteness, for the diminishing amount of light received from each star. The argument, of course, takes for granted the universal validity of the law that light does not suffer diminution as it travels through space — does not, so to speak,

at last go out. If this law fails in any part of the universe, the darkness of the background of the sky cannot be taken as a positive proof of the limited number of the celestial host. But no evidence exists of the cessation of light due merely to its passage through space, however extended the journey may be.

The above considerations give us indeed some knowledge of the form of our sidereal universe and assure us of its finite extent; but they give no satisfactory knowledge of its actual numerical dimensions. More recent methods, based chiefly on the study of special types of variable stars and on the visual, photographic and spectrographic analysis of the structure of the globular clusters, have enabled astronomers to form a more definite estimate of the tremendous size of the complex system of which our own solar system, vast and complex as it seems to us, is but a minute element. The estimates formed by different scientists vary, it is true, very considerably but even the smallest estimates are almost overpowering when the mind first contemplates their significance. According to these lower estimates, the arguments for which have been ably summed up and defended by Dr. Heber Doust Curtis, Director of the Allegheny Observatory, the Galaxy is so vast that a pulse of light starting from one edge of the system would take from twenty to thirty thousand years to reach the other edge though traveling all the while with the unabating speed of 186,000 miles a second. If, however, we accept the figures of Dr. Harlow Shapley, Director of the Harvard College Observatory, and they are supported by very strong arguments and are being confirmed by new lines of research, we must still further tax our imagination and contemplate a system of stars and nebulæ and clusters the outer members of which are separated by such extreme distances that a pulse of light would take from two to three thousand centuries to complete its journey from one confine of the Milky Way to the other.

And what shall we say of the hundreds of thousands of spiral nebulæ which seem excluded from the Galaxy and receding ever further and further away from us? Are they also parts of the same system situated at approximately the same great distances, as some suppose; or are they quite outside the galactic system, other "Island Universes" like unto our own but separated from us by distances a hundred times or more as great as that of the farthest stars in the Milky Way, yet bound to us by the slender thread of silver light that proclaims to us their far-off presence? What is the great coördinating principle that gives unity to all these elements? These are questions science cannot yet answer. We are convinced that there is a unity in it all; the whole visible creation must be the external fulfilment of the eternal plan of the Divine Architect of the universe; but this plan unfolds itself to us only slowly, part by part, and knowledge of it must be bought by long and patient labor. The order and beauty and sublimity revealed even by our imperfect knowledge of the heavens exert an enduring attraction on the mind and will doubtless afford, until the end of time, an ever widening field for the exercise of man's ingenuity, courage and devotion in his ceaseless search for truth.

TERRACES FIT FOR THE GODS AND GODDESSES OF MYTHOLOGY



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JUPITER AND MINERVA TERRACES, YELLOWSTONE NATIONAL PARK

FACING PAGE 4777

GEYSERS AND VOLCANOES

The Various Forms Through Which
the Earth's Internal Heat Bursts Forth

WAS OLD OCEAN MADE BY VOLCANO STEAM?

AMONG the minor but still highly picturesque evidences of the igneous agencies in the earth are certain hot or boiling springs called geysers. The term "geyser", derived from an Icelandic word meaning to gush or to burst forth with violence, is applied to those actively boiling springs which at intervals throw out columns of hot water and steam. These springs, associated with volcanic activity, appear to be restricted, as far as is known, mainly to three regions, Iceland, New Zealand and our own Yellowstone Park. Geysers were first studied in Iceland and in the North Island of New Zealand, but neither of those countries can claim the great number and varied beauty and activity that characterize the geyser fields of the United States. In the heart of the American Rockies, in the northwest corner of Wyoming and extending into Montana and Idaho is the wonderland of natural phenomena known as the Yellowstone National Park. In 1872 Congress set apart 3575 square miles in this region "as a public pleasure ground and game preserve". In 1891 another large tract was added to the park, making its area 5600 square miles, nearly three times as large as the state of Delaware. The Yellowstone Park is remarkable for its grand scenery, many snow-clad peaks, a dozen or more over 10,000 feet high, lying within and near its borders, but its main attraction is the constantly recurring phenomenon of minor volcanic agencies, over one hundred geysers and more than three thousand hot springs.

There are three great geyser basins in the valley of the Firehole River, all about 7000 feet above sea level. The upper is the most active, containing the Giant and Giantess, named from their great crater-size and force of action, the Beehive and Castle, so called on account of the shape of their cones, the Saw Mill and Lion, from the noise they make, and Old Faithful, from its regularly recurring eruption. The Giant spouts every six days, throwing a column of water and steam 10 feet in diameter to a height of 200 feet; this action held once for three hours, but usually lasts only a few minutes.

The most regular of all the geysers is Old Faithful, which for years after its discovery was almost clock-like in its regularity, and spouted a slender column of water 125 feet high at intervals of sixty-five minutes. Old Faithful is now becoming slightly irregular. Its lessening activity, like that of other geysers, may be due to a combination of partial choking of the underground water supplies and a slight local diminution of internal heat. The Miniature Geyser, the smallest on record, works industriously, but can spout its water only a foot high. A fine description of the action of the Castle Geyser is given by Lord Dunraven in "The Great Divide":

"Far down in his bowels a fearful commotion was going on; we could hear a great noise — a rumbling as of thousands of tons of stones rolling round and round, piling up in heaps, and rattling down again, mingled with the lashing of the water against the sides as it surged up the funnel, and fell again in spray. Louder and louder grew

the disturbance, till with a sudden qualm he would heave out a few tons of water, and obtain momentary relief. After a few premonitory heaves had warned us to remove to a little distance, the symptoms became rapidly worse; the row and the racket increased in intensity; the monster's throes became more and more violent; the earth trembled at his rage; and finally, with a mighty spasm, he hurled into the air a great column of water. I should say that this column reached, at its highest point of elevation, an altitude of 250 feet. The spray and steam were driven through it up to a much greater elevation, and then floated upwards as a dense cloud to any distance. The operation was not continuous, but consisted of strong, distinct pulsations, occurring at a maximum rate of seventy per minute, having a general tendency to increase gradually in vigor and rapidity of utterance until the greatest development of strength was attained, and then sinking again by degrees. But the increase and subsidence were not uniform or regular; the jets arose, getting stronger and stronger at every pulsation for ten or twelve strokes, until the effort would culminate in three impulses of unusual power. . . . The volume of water ejected must have been prodigious; the spray descended in heavy rain over a large area, and torrents of hot water, six or eight inches deep, poured down the sloping platform."

In the Middle Basin of the Firehole region is "The Devil's Paint Pot", a caldron of boiling, many-hued mud which bubbles and steams with a wonderful play of changing colors.

Photo J. E. Haynes, St. Paul

CASTLE WELL AND CASTLE CONE

The hot water ejected by geysers is always beautifully clear, but still it is highly charged with mineral matter, mainly dissolved silica, and round the orifices of the geysers there are incrustations of such matter that often assume beautiful or fantastic forms and colors. Thus, the Castle Geyser has made a beautiful white cone for itself, and the Great Fountain Geyser a broad, circular pedestal about two feet high. The tints assumed by the mineral deposits are produced by algæ, which grow luxuriantly in the hot water.

WHERE EARTH'S BOILING INTERNAL HEAT BURSTS STEAMING FORTH

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THE BOILING POOL OF POHUTU GEYSER, NEW ZEALAND

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AN ERUPTION OF OLD FAITHFUL, YELLOWSTONE PARK

The amount of water discharged by geysers is very large. The Excelsior Spring, even in its most dormant condition, pours more than 250,000 gallons an hour into the Firehole River; and Old Faithful contributes about three times as much.

Though Yellowstone Park boasts of the most numerous and famous geysers, Iceland, the birthplace of geyser study, must not be passed by without notice. This country is itself one of the wonders of the world — weird, grotesque, and sinister — a wonder of desolation. It is a land of fire and ice, of glacier and geyser, of lava and slush, of avalanche and volcano. Here "Nature breeds all monstrous, all prodigious things". It has no green fields, nothing but "raw-white and dull-black hues, like gulls' feathers strewed upon a roof of tarred shingles". An Icelander once described his native land as "nothing but bogs, rocks, precipices; precipices, rocks and bogs; ice, snow, lava; lava, snow and ice; rivers and torrents, torrents and rivers".

From the top of Odahahraun, a lava field extending over 1700 square miles, the surface of the earth resembles a gigantic, stiffened corpse, petrified, black as the night. All together, no less than 5000 square miles of the island are black with lava, and 5550 square miles are white with snow. Rising from this black-and-white desert are great volcanoes, such as Hecla (5110 feet). Most of the volcanoes are quiescent now, but Askja, whose crater is 34 square miles in extent, and 3000 feet deep, was in eruption in 1875, and covered about 2000 square miles with its ashes.

In a young volcanic district such as this it is not strange to find geysers; they are only one of many signs of volcanic activity.

The Great Geyser has built a mound of siliceous material for itself about 40 feet high, and from the saucer-like basin on its top a tube 10 feet in diameter descends about 74 feet. In its prime, it used to eject water to the height of 150 feet, but now the average height of its jet is only 70 or 80 feet. The sound of the geyser in eruption has been compared to the roar of an angry sea intermingled with the regularly recurring sounds of minute-guns.

The Strokkr has no regular basin, merely a funnel-shaped tube, narrowing from a diameter of 9 feet at the surface to 10 inches at 27 feet down. It can usually be made to erupt by throwing in turf or stones, the amount thrown in regulating the time of eruption. The Strokkr can spout higher than the Great Geyser, but its usual height is only 30 or 40 feet.

A third great geyser wonderland is found in the North Island of New Zealand, in the volcanic country round Lake Taupo and Rotorua. Here we find the greatest geyser in the world. Its tube, 80 feet deep, is situated in the middle of a hot lake lying in a crater formed during the great volcanic eruption of 1886. This tremendous geyser has not the beauty of the Yellowstone Park geysers, since the column of water it flings is muddy and inky-black, but it surpasses the Yellowstone Park geysers in violence, since it often throws its water column to a height of 500 feet, and on one occasion three times that height. At times it is dormant for weeks, and at other times it is active for weeks. Near Rotorua there are a number of geysers, but only the smaller ones are now active, and the Wairoa Geyser, which used to spout spontaneously to a height of 200 feet, will now play only when fed with bars of soap.

It has been found that the addition of certain alkaline substances, like soap or lye, makes the water somewhat viscous, causing it to retain the smaller steam bubbles till the accumulated volume of steam breaks out with a sudden lowering of pressure and increased eruptive power. Before the great eruption of 1886 two geyser lakes by their overflow had produced these marvelous siliceous encrustations known as the White and Pink Terraces. At the eruption these were destroyed. The White Terrace had about forty secondary terraces, and rose to a height of 150 feet, and the Pink Terrace was built up in fifty steps, and rose to a still greater height. Many a pen has tried in vain to describe their exquisite beauty. Those who have seen Cleopatra Terrace and Jupiter and Minerva Terraces in our own Yellowstone Park can readily imagine what they must have been like.

Before leaving the subject of geysers, let us look for a moment at the manner of their action. Expanding steam is evidently the motive power of the active geyser. The steam is most probably produced by contact of underground waters with heated rock masses, or hardening lava, or by hot gases and vapors emitted by neighboring pockets of molten rock. The explosive and intermittent geyser action is explained best by the theory developed by Bunsen during his study of the Great Geyser in Iceland.

The boiling-point of water is lowered under less pressure, will boil at a rather lower temperature. If the tube be wide and somewhat regular in shape convection currents will carry the highly heated and lighter lower layers to the top, equalizing the temperature, and if the heat is sufficient an ordinary boiling spring will result. If, however, the pipe is irregular, tortuous and constricted at some point, ascension of the heated bottom layers is stopped or partially checked, their temperature rises higher and higher, going above the ordinary boiling-point 212° F. on account of the pressure of the water above. Any

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CLEOPATRA TERRACE, YELLOWSTONE NATIONAL PARK

and raised as the pressure at the surface of the water is diminished or increased. Under ordinary atmospheric pressure at sea level, water boils at 212°. At the top of a mountain, where the atmospheric pressure is less, it will boil at a much lower temperature; at the bottom of a deep mine, where the atmospheric pressure is greater, a higher temperature is required. Now, in a deep pipe the water at the bottom is under the pressure of all the water above it, and so it requires a temperature of more than 212° F. to raise it to boiling-point, or, in other words, to convert it into steam, while water in the middle of the tube, being decrease of pressure, coming from the overflow of some of the upper-pipe water into the basin, will cause the water at and below the constricted part, already above the ordinary boiling-point, to flash into steam. A column of mixed steam and hot water is shot out; some of the water may return, more flows in from the rock fissures and the phenomenon is repeated with more or less regularity according to the supply of water and heat. A laboratory model built and operated on this theory works perfectly. Of course, lessening of heat and choking of the water conduits will diminish geyser activity.

THE HIGHEST GEYSER IN THE WORLD

Photo J. E. Haynes, St. Paul

GIANT GEYSER (250 FEET), YELLOWSTONE NATIONAL PARK

Volcanoes and geysers must be considered together, for they are undoubtedly akin. Geysers are just a kind of volcano, and volcanoes are just a kind of geyser, but volcanoes are much more magnificent manifestations of force. They are, indeed, the most impressive of all nature's forces, with the one possible exception of earthquakes. All over the world volcanic craters are glowing and steaming, grumbling and grumbling; and ever and anon, in paroxysms of violence, they devastate the mountain, whether it be active, as Stromboli, or dead, as the Puy-de-Dôme in France. Such hills and mountains may be of all shapes and all sizes, but they are usually conical and often very lofty. Orizaba and Popocatepetl, in Mexico; Cotopaxi and Aconcagua, in the Andes; Mount St. Elias, in Alaska; Kilimanjaro and Kenia, in Africa; Ararat and Damevend, in Asia, are all between 17,000 and 23,000 feet high. Many of their conical peaks are beautiful and picturesque. The Peak of Teneriffe

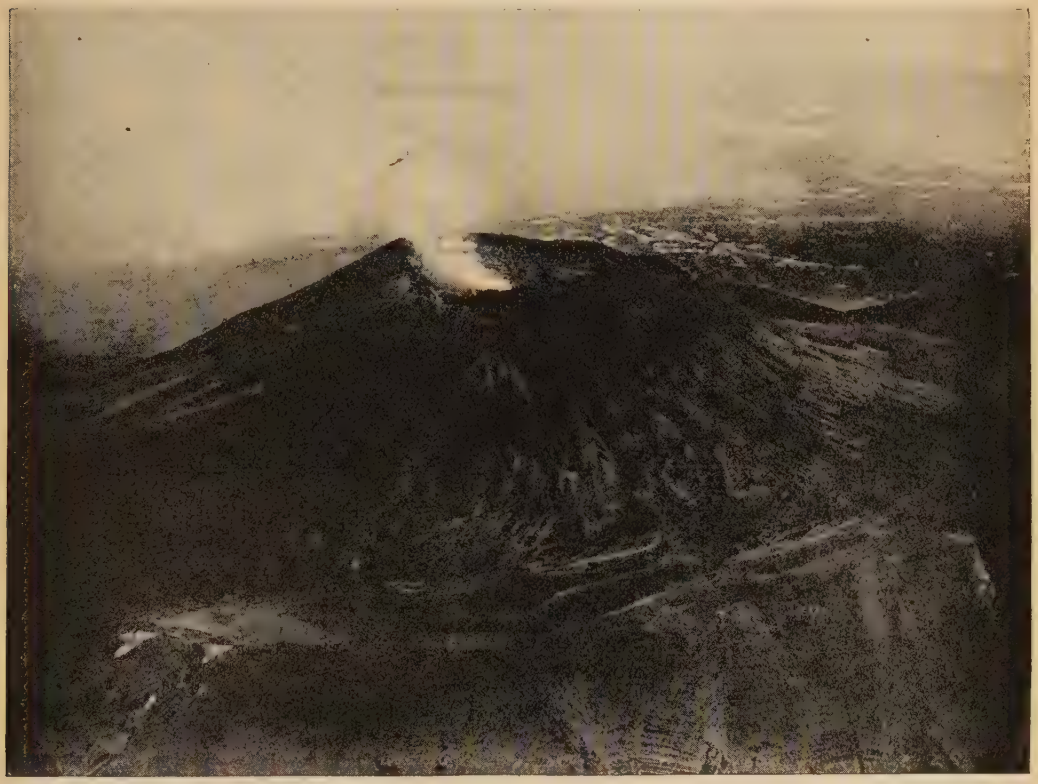

Photo International Newsreel

AIRPLANE VIEW OF MT. VESUVIUS AND THE BAY OF NAPLES

land with clouds of fire and steam, with broadsides of boulders and rocks, with rivers of lava and hot mud. Vesuvius, Etna, Hecla, Stromboli, are familiar names of fiery fountains. To our forefathers they seemed the porches of the infernal regions.

A volcano is a vent or fissure in the earth's crust, from which emerge, more or less violently, solids, liquids and gases, hot and incandescent, which materials sooner or later build up a cone about the vent. The term is now applied to the conical (12,192 feet), rising from the sea; Etna (10,570 feet), girdled by the Sicilian surf; Chimborazo (20,000 feet); and especially, Mayon (8970 feet), Philippine Islands, Mt. Osorno (7500 feet), Chili and Fujiyama (12,390 feet), Japan are all remarkable for beauty and regularity of shape, the last two being snow-capped.

The top of a volcano usually shows a more or less cup- or basin-shaped depression, called the "crater". The characteristic conical shape of a volcano is un-

doubtedly due to the manner in which the mountain is made. It is merely an accumulation of frozen lava, fragmental rocks and cinders ejected from a hole, and the material thus thrown out naturally assumes the shape of a cone with a funnel or pipe through its center leading to a cup-shaped cavity at its summit. The angle of the cone depends on the viscosity of the lava and the cohesiveness of the material ejected — the more viscous the lava, and the more cohesive the material ejected, the steeper will the cone be. The volcanic cones in the island of Réunion, Indian Ocean, which have been formed from very viscid lava, are about as steep as a thimble, while the volcanic cones of the Hawaiian lands, formed from fluid lava, have very gradual slopes, with bases up to 70 miles and more in diameter.

The composition of the cone of various volcanoes differs — some are composed entirely of cindery and slag-like fragments, others entirely of sheets of lava, and others of a mixture of both. The more massive volcanoes are usually built up out of alternate layers of lava-sheets and fragmentary material and volcanic dust; and crossing these layers in various directions there are numerous cracks filled with lava, which are known as "dikes". It may seem difficult to believe that volcanic mountains 15,000 or 20,000 feet high have been built up in this manner layer by layer; but it must not be forgotten that the process may have been going on for many thousands of years.

Photo International Newsreel

LOOKING DOWN INTO THE CRATER OF VESUVIUS FROM AN AIRPLANE

Mountains made in this way obviously are apt to be broken down as well as built up, and may change their shape considerably in the course of growth. Explosions or lava streams may tear away part of their summits, and in some cases their tops have been blown bodily off. Or new vents and new cones may be formed. During the last century Vesuvius changed its shape several times. In the times of the early Romans, its summit was a great, depressed

THE ITALIAN GIANT IN SLUMBROUS REPOSE

© Ewing Galloway, N. Y.

AIRPLANE VIEW OF NEW CONE IN THE CRATER OF VESUVIUS

plain nearly three miles across, where Spartacus the gladiator, with his followers, was besieged by a Roman army. After the great eruption of 79 A.D. it developed a huge crater, and within this crater a new cone with a smaller crater was formed. In 1822 a great eruption reduced its height by 400 feet, and produced a huge crater a mile in diameter and 1000 feet deep. In 1843 three small cones with craters had sprung up within this crater. The eruptions of 1872 and 1906 again changed its shape, and in 1922 a new cone 230 feet high was built within the old crater. All active volcanoes are subject to such alterations in shape; but the general effect of activity is to increase the bulk and height of the mountain.

Though each volcano begins as a small cone, and is a cone to the end, yet almost all the great volcanoes develop smaller vents which give rise to subsidiary cones. Etna has, for instance, hundreds of these secondary or "parasitic" cones, which tend to destroy its primitive conical shape, and the volcanoes of Hawaii have thousands of these parasites. In most cases the vent by which matter is ejected is cup-shaped or basin-shaped, and is called a "crater".

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THE SNOW-CAPPED FUJIYAMA, JAPAN

WHERE ASHES AND SNOW MAKE TREACHEROUS FOOTING FOR THE BOLD

© Ewing Galloway, N. Y.

THE CRATER OF EL MISTI (19,260 FEET), THE PERUVIAN VOLCANO

A crater twenty miles round on an island in the Pacific

The size of craters varies within very wide limits, and there would seem to be little or no connection between the size of the crater and the height of the volcano. The crater of Orizaba, a mountain 18,250 feet high, is less than 1000 feet in diameter; the crater of Popocatepetl, a mountain 17,500 feet high, is only about twice as large; while the crater of Haleakala, a mountain 10,000 feet high, on one of the Hawaiian islands, has a crater 20 miles in circumference.

Nor does there seem to be much connection between the size of the crater and explosive potentialities, for Krakatoa and Pelée had craters of very moderate size. According to Reclus, the most astonishing and interesting crater in the world is the crater of Kilauea, in the island of Hawaii on the southeast slope of Mauna Loa and twenty miles from its summit. This crater and its action will be described in a later chapter.

The peaceful lakes that form in the craters of dormant volcanoes

The Spanish word *caldera*, caldron, given first to a very large crater in the Canary Islands, is now used as a generic name for very broad and comparatively shallow craters. These, at least in some cases, have been formed most probably by explosions which blasted off the top of the original cone, thus widening the crater and at the same time diminishing its depth. Many of these calderas are filled with water, forming lakes. The most beautiful and picturesque of these, Crater Lake, is now the center of Crater Lake National Park in southwestern Oregon on the crest of the Cascade Mountains. This lake of pure spring water, twenty square miles in extent and, in places, 2000 feet deep, is 6177 feet above the sea level, and is surrounded by rock walls varying from 500 to 2000 feet high. The Indians called it "the Sea of Silence" and Joaquin Miller has named it "a sea of sapphire set round by a compact circle of the great grizzly rocks of Yosemite".

The activity of volcanoes usually varies greatly from time to time. As a rule, periods of partial or complete inactivity alternate with periods of paroxysmal violence. Until the eruption of 79 A.D. Vesuvius had been in repose for centuries. The eruption of Krakatoa took place after a slumber of two hundred years; and many volcanoes which seem now moribund or dead may again burst forth into active life. Some volcanoes are constantly active.

A volcano that has been pouring forth lava for 2000 years

Stromboli has been pouring forth lava for more than two thousand years. Izalco, which was born in 1770, has been in constant eruption ever since. As a rule, the great volcanic eruptions have been those of volcanoes which were dormant for many years; and those that work constantly are comparatively tame. Some, such as the great volcano of Palma, in the Canaries, Mt. Shasta, California, Mt. Hood, Oregon, Mt. Adams, Mt. Baker and Mt. Rainier in Washington, seem absolutely dead. Some have been dead so long that the great mountains they built in the days of their activity have been worn down almost to their very foundations. The peaks of some are snow-clad, and their slopes, if not forested, are being so carved and furrowed by eroding agents, that they are fast losing their characteristic shape.

There are several thousand volcanoes on the globe, and about 500 of these are known to be alive. The distribution of volcanoes is interesting. In a general way they are distributed in a linear fashion, and are found along three main lines, which run north and south. One line runs along the ridge which divides the Atlantic Ocean longitudinally into two basins. Along this ridge rise a number of volcanic islands, and on many of these are active volcanoes. The island of Jan Mayen has one; Iceland at least thirteen, the Azores six, the Canaries three, the western coast of Africa eight, the West Indies six and there are, besides, three submarine volcanoes in the Atlantic. This line is about 1000 miles in length, and with its branches contains about 50 active volcanoes.

A second line of volcanoes starts near the Behring Straits, and runs all the way down the western coast of North and South America. This line is about 8000 miles in length, and contains about 100 active volcanoes. The third great line also starts at Behring Straits, and runs down in the chain of islands between the Pacific region, two. All together, this line stretches for 10,000 miles, and, with its branches, includes over 150 active volcanoes.

A fourth line, but not nearly so important as the other three, includes the volcanoes of Mauritius, Réunion, Rodriguez and the eastern coast of Africa. These four lines include almost all the active

PART OF CRATER LAKE, OREGON

and Indian Oceans. In the peninsula of Kamchatka there are twelve active volcanoes; in the Aleutian Islands, thirty-one; in Alaska, three; in the Kuriles, ten; in Japan (inland to the south), twenty-five; in islands off the southeast of Asia, fifty; in New Guinea, five; in Java, nearly fifty; in New Zealand, three; in the Antarctic volcanoes of the world; they all run in proximity to the sea, and the two largest bands form an almost complete circle round the Pacific Ocean. Another point to be noticed with regard to the distribution of volcanoes is that volcano bands usually run parallel with great mountain ranges.

The proximity of volcanoes to the sea has often been explained on the theory that they are due to the ebullition of seawater which has gained entrance to the hot rocks of the earth through fissures in the crust. The nearness of some volcanic chains to the sea is only relative to the size of the continental masses. The long volcanic line which runs down the west coast of the western hemisphere varies from 30 to 250 miles from the sea and in this line are many active cones, like Cotopaxi, far inland and not near any body of water. Now it is highly improbable that there are any bodies of ground water six miles below the surface, for at that depth there are no fissures and no pores. So the enormous amounts of steam from even small volcanoes in action may naturally be considered a fresh contribution to the existing ocean supply. During a single eruption of Etna nearly 600,000,000 gallons of water were given off as steam, and a small parasitic cone of the same volcano sent out 460,000,000 gallons in 100 days. The main bulk of volcanic gases is steam and all active volcanoes are contributing. They do not draw on the ocean or ground waters for their supply, so we may conclude that all the ocean waters are the accumulated outpourings of volcanic waters of the earth's interior from the beginning of volcanic times.

Volcanoes have also pushed out incredibly great masses of solids from the earth. The thousands of extinct and active volcanoes, from small hills to giants of three miles in height (and even six miles like Mauna Kea and other Hawaiian cones measured from the ocean bed), all owe their mass to the earth's interior. The average annual discharge of sediment by the Mississippi is over 560,000,000 tons; Mt. Pelée in a few hours, during the eruptions of 1902, belched out 500 times as much in volcanic dust. These great expulsions of solids leave great depressions. Why shouldn't they, in times gone by, have formed the ocean beds? So, volcanic action, we conclude with some show of reason, may have hollowed the ocean deeps and filled them too. A speculation, of course, with not a very full understanding of the incredible grandeur of natural forces and the time and materials at their disposal.

Photo World Wide Photos

MOUNT ETNA, SICILY

Let us look for a moment at the phenomena of violent volcanic eruptions. Usually there are premonitory symptoms, such as earthquakes, rumblings, sometimes disappearance of a lake, or rise and fall in its levels, or an increase in the activity of the volcano if it be already in action. Then comes the actual paroxysm. Out of the crater rush enormous quantities of steam, mixed usually with small amounts of other gases, and carrying with them stones, rocks, ashes, lava and various other ejecta. The rush of steam is accompanied by a prodigious roaring sound, and the ground shakes and trembles. The column of steam usually goes vertically upwards to a great height, and assumes the form of a pine-tree, to which it was compared by Pliny. In many cases, jets of liquid lava go up with steam, and the friction of the steam against the crater walls creates electricity, so that peals of thunder are heard, and forked lightning flashes to and fro through the column. At times the column is laden with incandescent particles, and occasionally there are gases in it which are set ablaze; and in all cases it is lit up by the glowing lava in the crater, so that it seems on fire. During the worst eruptions the column is so thick and so black that it hides the sun, and makes an impenetrable, pitch darkness. The condensation of the steam causes torrential rain, and muddy rivers flow down the sides of the volcano, and may bury cities, as Herculaneum was buried, at the base.

AN ERUPTION OF ASAMA YUMA, JAPAN

The height to which the column of steam and its contents rise may be tremendous. In 1779, Vesuvius is said to have thrown a volume of cinders and steam to the height of 10,000 feet; and on some occasions its column of vapor was estimated to reach 23,000 to 26,000 feet, while ashes from Krakatoa mounted to a height of seventeen miles. The amount of lava and solid matter ejected varies. In some cases, as in the case of Mont Pelée, the main discharge is steam; in other cases there is a tremendous amount of lava, and in other cases a huge mass of cinders, ashes or pulverized rock. In some ways lava is the most characteristic product of a volcanic eruption, but nevertheless some eruptions produce no lava. In the great outbreak of Mont Pelée no lava was discharged — only prodigious quantities of sand and stones and incandescent dust.

As a rule, however, when the volcano has cleared its throat, lava begins to flow from the crater, or even to spout high into the air like a fountain of molten metal. Usually the lava pours over the edges of the crater, or through fissures in its sides, and when a crater is much fissured it seems to "sweat" lava from numerous pores. Flowing lava is at first white-hot, and steams as it flows. As it cools it grows red and then black. The rate of flow is often at first very rapid, but of course it varies with the viscidity of the lava, and with the slope of the ground. When it reaches a steep place it pours tumultuously over it, while on gentle slopes it may move very slowly. Also, as it cools it becomes more viscid, and runs with greater difficulty.

A stream of lava that was still hot 43 years after it had erupted

The surface appearance of the cooled lava depends on its chemical nature, and on its viscidity when flowing. Viscous, sticky lavas break up, as they cool, into brown or black clinkers or slags, which grate together as the lava continues to flow, and often get piled up into mounds and heaps. More fluid lavas take on a twisted rope-like structure, which Professor Geikie likens to the scum of a sluggish river. The heat of lava is very great — in many cases being more than 2000° F. It fuses even flint. It is a bad conductor of heat, and cools very slowly, so that, when it is cool enough at the surface to be walked upon, it may be red-hot below. Many remarkable instances can be given of the slowness with which lava cools. In 1830, steam was still issuing from lava which had flowed from Etna forty-three years before.

Jorullo, in Mexico, discharged lava in 1759; twenty-one years later a cigar could be lighted at its fissures, and eighty-seven years later two columns of steam still rose from it. This slow cooling of the lava obviously suggests that the crust of the earth, though cool, may contain molten matter a very short way down.

The vast rocks that are flung far and wide by an active volcano

Besides lava, as we have said, volcanoes discharge huge quantities of rocks, stones, cinders and ashes. It is difficult to get authentic measurements as to the size of the rocks and stones a volcano can hurl, and the distance to which it can throw them. During the eruption of 1779, Vesuvius hurled cinders to a height of 10,000 feet, and in 1815 Tomboro, Sumbawa Island, covered the sea for miles with pumice-stone more than 3 feet deep, so that ships could hardly force their way through it. Among the ashes which buried Pompeii are stones eight pounds in weight. Antuca, in Chili, is said to send stones flying to a distance of 36 miles. Cotopaxi is said to have flung a 200-ton block 9 miles, and Asama, in Japan, according to report, tosses about blocks of stone 40 to 100 feet in diameter.

The darkening of the sky and ruin of the soil wrought by volcanic dust

But even more astonishing than all this is the distance the dust belched forth by volcanoes may float, and the great proportion it often bears in the total amount of material ejected by the volcano. When Coseguina, in Nicaragua, blew to pieces, it is computed that 6500 million cubic yards were cast to the winds. The dust was carried at least 800 miles, and sprinkled an area of 1,500,000 square miles. When Tomboro erupted, in 1815, dust fell on the island of Borneo, 870 miles away, in such quantities that the inhabitants still date their years from "the great fall of the ashes". Similarly, after the great eruption of Skaptar Jökull, Ireland, in 1783, ashes fell in such quantities in Caithness, Scotland, — 600 miles away, — as to destroy the crops, and that year is still spoken of by the inhabitants as "the ashie" year. In 1877 the dust from an eruption of Cotopaxi plunged the city of Quito into pitch darkness. The dust from Krakatoa darkened the sky for 150 miles from the mountain, and fell in appreciable quantities 1000 miles away.

The darkness caused by the dust is one of the most trying and terrible features of a volcanic eruption. To be shut into an impenetrable darkness, lit only by lightning flashes and the glow and glare of molten lava, must be an experience to try the stoutest heart. To escape from the night of terror made by the dust of Coseguina, in Nicaragua, men, women and children fled in a body from the mountain, and it is recorded that animals, such as monkeys, serpents and birds, joined the fugitives, "as if they recognized in man a being endowed with intelligence superior to their own". But, strangely enough, this dust, which at first brings on the darkness of night, is ultimately the cause of beautiful and gorgeous skies. Floating in high heaven, and sometimes making several circuits of the globe, the fine volcanic dust refracts and reflects individual colors of the sunlight, and produces surpassingly beautiful sunset and sunrise effects all over the world.

We have already mentioned the torrents of rain and mud that are often accompaniments of a volcanic eruption. Where there is dust, rain soon makes mud, and the deluge of water from the condensed steam soon converts the volcanic dust into a sticky mud that overwhelms and buries all it meets. By such a flood of mud Herculaneum was buried during the eruption of Vesuvius in 79. The great eruption of Cotopaxi, in 1877, covered many villages with a deposit of mud mixed with blocks of lava, ashes, pieces of wood and lumps of ice. Whole forests were laid low.

LAVA FROM VESUVIUS POURING IRRESISTIBLY OVER A MODERN VILLAGE

A special class of volcanoes, the submarine volcanoes, must be given a word. Etna, Vesuvius, Stromboli and many other volcanoes had their birth under the sea, and no one knows how many active volcanoes may be at work in the ocean depths. Often they throw up cinders and steam, and agitate the surface of the sea. Occasionally they betray their presence in a very sensational way. At times they elevate a new island into the air, and drag an old island down into the sea. St. Michael's, in the Azores, is a favorite place for these emergences and submergences, and on several occasions new islands have come and gone. The Mediterranean, too, is accustomed to islands that appear, and then disappear. In 1831, between Sicily and Africa, a new island called Graham Island, made of lava and cinders, suddenly appeared. It reached a height of 200 feet above water, and attained a circumference of three miles, but it melted away again, and in 1832 no signs of it could be seen. Between Sicily and Greece new islands are often thrown up, but as quickly as they come they go. Some islands, however, thrown up by submarine volcanoes, do last. Three islands of the Alaska-Aleutian chain are good examples. The first Bogoslov appeared about 40 miles to the west of Unalaska Islands in 1796, after an eruption. In 1883 another eruption about half a mile to the northwest threw up a new volcanic cone of black sand and ashes, known as new Bogoslov, and connected with the elder by a low-lying beach. Another island, called Perry Island, larger than either of the others, made its appearance in the immediate neighborhood in 1906.

Volcanoes are built up out of material pushed out from the earth's crust, but it is not necessary that all ejected material should grow up into cone mountains. In some instances, in the case of what are known as fissure eruptions, lava flows out of a fissure in the earth's crust, and may cover a large area without the production of anything like a volcano cone. Some of these fissure eruptions have taken place on a huge scale, and have covered enormous areas with lava.

The vast seas of lava that flooded parts of India and North America

In Iceland such fissure eruptions have been common. In 1783 two streams of lava issued from a twenty-mile fissure, and flooded respectively 40 and 28 miles. Another stream of lava 60 miles long flowed from a fissure in prehistoric days; and the great lava-desert of Odahahraun, which covers an area of about 1700 square miles, is also a product of a fissure. In the northeast of Ireland, there is evidence of great lava leakage in Tertiary times. It has been said that altogether no less than 40,000 square miles in Britain were at one time under a sea of lava which in some places was 3000 feet deep. In Africa large tracts of Abyssinia are covered with fissure lava, but in India and North America the best known examples of fissure outflows are to be found. The Deccan region of western India is covered for over 200,000 square miles with lava, in places 6000 feet deep. In northwestern United States, parts of Washington, Oregon, Idaho, Montana and California, lie under a sea of frozen lava nearly 200,000 square miles in extent and 3000 feet deep.

When we come to consider the causes of volcanic eruptions, we find ourselves largely in the region of conjecture. We have to discover both the source of the molten materials and the mechanism of its ejection.

Theories that have been brought forward to explain eruptions of volcanoes

This investigation depends on our knowledge of the earth's interior and this knowledge is very little indeed. Some geologists are of opinion that the heat necessary for volcanic action is due to the gradual shrinking and compression of the earth yielding to the force of gravity. This would cause a flow of heat outwards and its concentration in particular regions would result in the melting of rocks. Other scientists, since the discovery of radioactivity, attribute the production of heat to the disintegration and breaking down of radioactive materials. However, the prevalent view at the present time is that the needed heat is primal, the interior remnant of heat in a sphere once molten or intensely hot. The old idea of a complete liquid interior is not held now by any geologist of note. But lava requires molten rock; whence does it come? According to some there are already in and below the crust of the earth pockets of lava due to local increase of heat. Others hold that most of the rock is already above its ordinary melting point, but kept solid by the pressure of overlying rock masses. Release of this pressure means production of lava lakes in the earth's crust. The ascension of the molten mass, with its originally absorbed gases, magma as it is called, is produced probably by variations in pressure caused by shifting of the segments into which the earth's crust is broken up. This again is almost pure speculation. Once the magma moves up, its enclosed gases and vapors break out, producing the eruption and its consequences.

Will it ever be possible to control for man's needs the tremendous reservoirs of energy stored in volcanoes and other igneous agencies? Towards the end of 1923 a Chilean corporation advertised for some enterprising wealthy individuals who might wish to buy a quiet tame volcano guaranteed to deliver a few hundred thousand horse power. Our knowledge of what we do not know of the earth's interior makes us very suspicious of the "guarantee". Still, untamable rivers and headlong cataracts have become docile to man's intellect, and, in the not too distant future, it may happen that some transcendent engineering genius will curb the fiery paroxysms of volcanoes and guide them to steady power.

CONTROL OF LIFE BY MAN

How the Living Population of the Earth is Being Changed
by Man's Activities as Destroyer, Preserver and Creator

THE FOOD PROBLEM AS MEN INCREASE

LOOKED at from a planetary aspect, plainly all that we have been discussing throughout many past chapters of this section has been the assertion of one form of life, *Homo sapiens*, against all others. We have seen that the struggle for life between one species and another is general throughout the living world, and must, indeed, have been one of the great factors of progress. Under the waters of the ocean, in the soil, in the air, on the mountain, in the forest, we perpetually see species struggling with one another, ousting or succumbing to one another, and changing the face of the world accordingly. Man's efforts to establish himself, we see, must be looked upon as similar in principle to those in which the sponge, the starfish, the mold, the monkey, is engaged. He is simply one species struggling for life with and against all others.

But man is so incomparably endowed that the struggle takes on a new aspect where he engages in it. He takes the guise of a conqueror. So skilful is he that, though his birth-rate is extremely low, he yet is the one living species which incessantly, relentlessly, increases in numbers, and has been doing so for ages past. While other species merely manage to maintain their numbers, at best, notwithstanding the enormous numbers of their offspring, man is in a different case. The rest of the living world, where he does not interfere, exhibits what we have called the balance of nature. After ages of struggle, a balance between the numbers of species has been attained, wherever the environment is constant. Of course, if the environment be altered, the alteration will surely favor one or more species as against the rest, and the balance will require to be readjusted accordingly. But where the environment remains fairly constant, or changes only around a mean, like the climate of the Azores, the balance of living species remains very constant, only fluctuating from year to year in accordance with climatic fluctuations.

But to this, which is illustrated in every part of the world, man is the standing and stupendous exception. Though he has inhabited the globe for thousands of years, he has not yet by any means maintained his maximum of numbers, nor has he established any condition of balance with the rest of living nature. In fact, the idea has not occurred to him. He looks upon himself — not, indeed, without some excuse — as the "lord of the earth", upon all other living things as made for his use and convenience, and he proceeds on his ever-multiplying course without a doubt or a question. So immense are the changes already wrought by the activity of man upon the face of the earth that an observer situated upon the moon with a modern telescope could readily detect them.

All of these changes have involved an alteration of that balance of nature which obtained until they were effected. Where now a city stands was once forest or field, covered with its own appropriate forms of life, or even a lake or bog, no less rich in the forms of life which can flourish there. Man has expelled them and replaced them by himself. And within the last few decades the nature of his advance has become profoundly modified, thanks to the peculiar instrument he uses, with consequences, achieved and imminent, which it behooves us now to study.

Needless to say, the other forms of life, true to their nature, have always put up what fight they could against the advance of victorious man. An inexperienced observer would naturally expect that the weakest and smallest forms of life would have been defeated first, and that any outstanding species which man had still to fear would be the largest, the most powerful, and the most intelligent — those which, in the last respect, notably, could fight man to some extent with his own weapons. Nothing of the sort has been the case. On the contrary, the earliest records that we have of man at all are the remains which show that some creature existed which could kill and eat and use the cave-bear and such formidable animals of the past. That creature was man; and we thus find that his mind has always enabled him to gain the mastery over the forms of life which come nearest to him.

The easy mastery by man over the more powerful animals

Wolves roamed, not so very long ago, over areas that now serve as thoroughfares in our modern cities; man has defeated them. The possession of considerable intelligence on the part of other animals has never availed them against man, for the gap between the best of theirs and his is too immense. They never had a chance when it came to "brains". Thus the "wild animals", as we call them, have been conquered long ago, wherever man had made up his mind to do so. The struggle for life, as we have seen, has not been between man and the forms of life which most nearly rival him, but between man and the very lowest forms of life, such as the tubercle bacillus, than which no humbler form of living thing is certainly known.

Where some measure of intelligence was unavailing, the methods of the secret poisoner have long succeeded against man, and large tracts of the earth's surface have been held against him in these ways. But the knowledge of which the essentials were obtained in the nineteenth century has changed all that. Intelligence has come to suspect and, lastly, to identify the poisoner.

Man's growing mastery over secret poisonous things

Already man has been enabled to establish himself in large numbers, as in the Canal Zone, where formerly he could not survive. The present numbers of our race, perhaps some sixteen hundred millions, must indefinitely increase, it would appear.

But we have forgotten something. The struggle for existence is a fact, and one which man illustrates no less than any other living species; but it is not the whole of the facts. There is also the interdependence of species; and there is no species which more completely demonstrates a dependence upon others than does man.

As an animal in body, he is, like all other forms of animal life, dependent upon the existence of vegetable life, which he is constantly engaged in destroying, and in replacing with his paving-stones and trolley lines; as a mammal, he very largely depends for his survival and health upon milk and the various products of milk; as a species, therefore, he is very largely all but a parasite upon the cow and the goat and the ass. For hosts of other purposes he is dependent upon other forms of life; the existence of a city could not long be maintained without the substances of animal and vegetable origin, such as leather and wood, which man employs. The paper upon which these words are printed was manufactured by man, but it was in the first place manufactured by vegetable life, no less than the original papyrus from which our modern word is derived.

Will man conquer his dependence on animals and vegetables?

It is always imaginable, no doubt, that man may learn to make for himself the equivalents or superiors of various animal and vegetable products upon which he depends today. Though as yet "there's nothing like leather", there may be something better some day, and synthetic rubber appears to be achieved. We are not even entitled to say that man's intelligence may not some day enable him to construct proteins, starches and sugars by trans-

formation of the energy of sunlight, without having recourse to the powers of the green plant. Meanwhile, however, nothing is more certain than that man is destroying other forms of life, and replacing them by himself, to an extent which cannot indefinitely be maintained.

Take the British Isles as an illustration. Only a small fraction of their food is produced upon their own soil. The balance of nature has been utterly upset, and we have one species existing in numbers which have no feasible correspondence to the rest of life. This state of things, presented upon those islands, could not, of course, exist upon the whole area of the world. There can never be more human beings than there is food to feed.

Until the day on which man succeeds in deriving all he needs from sunlight directly, he has to recognize that he can command nature only by obeying her, and that his career of conquest over other forms of life must be qualified by the fact that he is dependent upon what he conquers. He is hacking at the ladder which supports him, and he must think again. Already, in his great cities, the difficulties of supplying enough food — that is to say, vital products — to his young are so great that they habitually die like flies. It behooves him to recognize the elementary conditions of his tenure of the globe.

Man as the world's spendthrift and improvident heir

So preëminent is he in intellect, in the knowledge which is power, that man not unreasonably regards himself as the owner of his planet, of which he proposes to take control, and which he intends to administer as he will. At present he can be looked upon only as a spendthrift and improvident heir of the vast and ancient inheritance which he has lately, having reached his majority, begun to control. Its resources are stupendous, and he goes gaily ahead, not thinking of the morrow. He will not exhaust the sunlight, nor the air, nor the ocean. Let him do what he will, enough and to spare of these will remain. But the other forms of life are not in that category, and he does not know it.

If he wants diamonds, he goes and finds them; if he wants furs, he goes and *kills* their owners and dispossesses them. It is this taking of life that stands apart from all the rest of man's activities. He has no idea how murderous he is. He thinks of himself as "civilized" domestic, and gentle. Never was so fierce, so insatiable, so destructive a creature contrived.

Man as the insatiable destroyer of what may be invaluable life

He takes life, to some extent, for fun, but to an immeasurably greater extent for use; and he simply chooses to forget the conditions on which the supply of such life can be maintained. After us, the deluge, is his motto. Not merely rare and lonely forms of life are disappearing before him, but also forms of life which can be of immense and irreplaceable service to him. He can build motor-cars that beat horses, but he cannot build motor-cars that will supply him with the anti-toxin of diphtheria when the breath of life can no longer enter his choking throat.

We cannot afford to exterminate forms of life on every hand, as we do at present. An ape is only an ape, and man may think it wise and right to replace apes by men; but there are services which the blood and body of the ape, just because it is so near mankind, can perform for our species, and which no other living races can perform. But the apes are rapidly going, and it seems probable that before long they will be extinct. Now, anyone or anything can kill, but creation is not so easy. When auks or apes are once destroyed they cannot be restored, any more than we could restore the dinosaur or the coal-bearing ferns if we wanted to. As things go at present, posterity will blame us, and rightly, for many outrageous pieces of irreparable destruction which we are now committing in our ignorance and carelessness.

If we look properly at human history, we realize that man has been dependent upon the rest of the living world from the first, and that his progress and numerical increase have essentially depended not upon his destruction but upon his *cultivation* of other forms of life.

Man's triumphs dependent on the cultivation, not the destruction of life

That is the remarkable manner in which he has triumphed. It is not wholly unique, for among the ants we know of species which maintain other forms of life, as slaves, or as a kind of "cow" yielding a sort of "milk". Apart from this case afforded by a wonderful insect, there is no parallel to the fashion in which man, seeking to maintain his species against all others, has cultivated and maintained the life of other species to that end.

Students of the history of civilization require to define its earliest stages, or preliminaries, in terms of the forms of life which man was learning not to destroy but to produce. They recognize a pastoral stage, when man throve by the use of flocks and herds; and we see that his success depended upon the intelligence and patience he was able to employ for the domestication of the animals upon which he depended. The ethical and vital advance, from the hunter to the shepherd, is immense and almost incalculable. Primitive man hunted his prey exactly as the lion, or the shark, or the spider does. It was a revolutionary step forward when man — or, as some writers have supposed, woman — learned how to tame and breed the animals upon which he depended, so that, instead of merely taking life, he conferred it, and then used it. The case of the Eskimo and the reindeer is as perfect an illustration of dependence on a preserved animal as may be needed.

Man's first culture of life for the life of his own species was doubtless concerned with certain animals. But students of human beginnings recognize an immensely important step when man the hunter, later man the herdsman, became man the planter. Agriculture comes upon the scene. Observing the ways of nature, man decides to supplement her efforts, and to sow, upon his own account, the kind of seed which he knows will yield him food in its season. Long ago Darwin pointed out that we have no instance of one species existing or struggling for another. The members of a given species will very often live or die for each other, but each species for itself is nature's way. Here, as in so many other cases, man transcends, as it were, the natural order. Incomparable as a destroyer, he becomes unprecedented as a maintainer and even creator of life. Over vast areas of his planet he decrees that certain forms of grass, called cereals, shall be the dominant form of life. He prepares the ground, he destroys other vegetable forms which he calls weeds, he sows the seed and he covers thousands of square miles with these grasses, upon which he proposes to browse in a few months to come.

Man's need to prepare the way for more life of his own species

The fundamental character of this relation — Man and Grass — was largely forgotten in the nineteenth century, with its triumphs in the realm of machinery. But hunger remains, and the law of the conservation of energy, which declares that if man is to use his body mechanically it must be fed with fuel. The twentieth century, with its unheard-of aggregations of population — has the reader any idea of the population of this country only a century ago? — must return, and is indeed returning, to some comprehension of the elementary truth that man, as a living species, is not independent of the rest of life, and that, if he wishes to maintain himself in the world, not the destruction but the creation of life is his only means to that end.

The twentieth century will witness, as never in history before, the intelligent and provident employment of man's powers, both of destruction and of creation, so that the balance of the living world shall be readjusted in his favor. Already, in its first decade, the century placed on record an extraordinary achievement in destruction — the abolition, in large measure, of certain mosquitoes which are inimical to the life of man. That process will be carried, of necessity, much further. Many parasite-conveying insects must be abolished. The domestic fly must go. The tubercle bacillus must go along with the leprosy bacillus, and the undetermined living cause of typhus fever. But we are

to observe that, with all this destruction of dangerous and parasitic life, there must go a construction of the life upon which, in truth, we ourselves are all but parasitic.

Every disease that is controlled or abolished, such as malaria or yellow fever, means that an immense increase of population suddenly occurs, involving a similar increase of the demand upon the food resources of the globe; and those food resources involve man's creation of life of one kind, for his own preservation, while he destroys life of another kind.

The danger of man being a too jealous tenant of the earth

We have already admitted, for the sake of accuracy and logic, that man might conceivably learn how to construct what he wants from inorganic materials by the aid of the energy of sunlight. Meanwhile, and for ages to come, if not forever, man must find that the living laboratories which he has employed for so long are vastly superior to and more resourceful and more economical than any which he can contrive. Further, the existence of other forms of life adds to the value and interest of man's life in a host of ways. He cannot afford to be too jealous a tenant of his globe. But undoubtedly he will continue, throughout the ages to come, the process of control over other forms of life which he began when first he tried to tame useful animals; and nowadays and for the future he has resources of power which are already almost staggering to contemplate.

Will man pass on from success in perpetuation to success in creation?

We have called some of his actions by the name of "creation", when "perpetuation" would have been a more accurate term. Certain forms of life, already existing, have been useful or pleasing to him, and he has favored, perpetuated and multiplied them, just as he has disfavored and destroyed other forms. But the recent discovery of some of the laws of heredity has endowed man with new powers. These are so remarkably analogous to those already obtained by chemistry that we cannot omit to notice the resemblance.

Chemistry made such advances in the nineteenth century, thanks to analysis, or the breaking down of compounds into their elements, that a new chemistry arose which we call synthetic, or "putting together". Until analysis has been achieved, synthesis must obviously be impossible. The chemist today is in large measure a creator. Not merely does he succeed in constructing, by his processes, compounds hitherto made by other forms of life alone; in the chemical laboratories of the world there now exist — and beside many a sick-bed and on many a toilet-table — chemical compounds which have never existed before. The atoms compounding them have existed for untold ages, but they have never been combined in such ways. Man has conceived these compounds, and called them into existence for the first time, to his great and increasing advantage.

An example of how man may call new beings into existence

But in the twentieth century man is proceeding to do, for living forms and combinations, what he learned in the nineteenth century to do for molecules. Mendel and his followers have begun to teach us the laws of combinations, in the structure of organisms, just as Dalton and his successors taught us the laws of chemical combination. And already there exist forms of life in the world which never existed before, and which man has deliberately called into being. Man, the destroyer and preserver, becomes man the creator as well.

If he desires to be able to say so much of any species, he must call it into being himself by his own creative intelligence, and that is precisely what he is now proceeding to do as the following illustration shows:

A strain of bees harmless to handle has been successfully developed by a man named Burrows. These bees, which have been obtained by mating a Cyprian drone with an Italian queen, are very active workers, and Mr. Burrows claims that they are less liable to disease than the ordinary honey bees. The new bees are not stingless, but the sting is innocuous. One hive in one year yielded over 200 pounds of honey.

The right of man to destroy degenerate forms of life

The prospect of the future thus begins to open out before us. Man will assume conscious and responsible control over all forms of earthly life, animal and vegetable. He will not permit himself to act in the interests of the present alone; above all in directions where his action is irrevocable. No useful form of life must be permitted to become extinct through sheer carelessness and neglect; and the higher the form of life, the more stringent must be the application of this rule. The earliest and most essential stages of man's control of all earthly life must undoubtedly be destructive. He must exterminate, either by direct attack or indirectly in various ways, every form of life that is parasitic upon him. He must further exterminate many forms of life, innocuous to himself, which are parasitic upon creatures precious to him — such creatures as the ox, the horse and the sheep. This destructive process need not be regarded as impious, nor as depriving the earth of ancient and respectable forms of life. The parasites peculiar to man are of recent origin, more recent, necessarily, than his own, and they must all be regarded as degenerate. He has brought them unwittingly into existence, by furnishing them with the particular kind of food material — his own tissues — upon which they can thrive, and also by such conditions as those of cities, which breed in dirt and darkness such microbes as the tubercle bacillus.

The increasing knowledge of how vegetable life grows from the soil

The same is largely or wholly true as regards man's domestic animals, and the various plants, such as the vine, which he has, so to speak, domesticated. He has established artificial conditions, of overcrowding, confinement, etc., for such creatures, as for himself, and has thus indirectly called into existence the many parasites which can thrive upon them in these conditions. What man has thus called into existence he is surely entitled to destroy for his own advantage.

Man's always unique and astonishing practice of increasing in numbers will necessarily become all the more conspicuous as he learns thus to control and abolish the principal causes of the death-rate among his species. The problem of food supply will thus become ever more urgent, as the number of candidate-mouths increases. We have discarded much of what Malthus taught, but we can still benefit by his warning. The preservation of certain forms of life, and of the edible grasses above all, follows as the basic necessity of man's existence in anything like his present — and much more his future — numbers. This seems simple enough in such a case as that of wheat, but our modern study of the soil has begun to teach us that the pyramid or ladder of life upon which the human species stands is by no means so simple as we used to suppose. Bread is the staff of man's life, but the life of the wheat-plant requires many living staves of its own. The soil is a theater of the most extraordinary and complicated vital activities. Already, in many a laboratory Metchnikoff's disciples are engaged in the culture of microbes for the prolongation and protection of the life of man; but no less important is the cultivation of the various microbes which exist in the soil, and are necessary for the life of wheat, and thence of man.

How man will become a breeder, as well as a destroyer, of bacilli

Much has already been done in this direction by the U. S. Department of Agriculture. Man will eventually find himself compelled to breed certain bacilli no less earnestly than he destroys others; and the most recent aspect of bacteriology, as exemplified in the work of Metchnikoff, consists in the attempt to produce certain new kinds of bacilli, with new characteristics which may be in one way or another useful to man.

Thus the living population of the globe, animal and vegetable, visible and invisible, is being daily changed by man's activities as destroyer, preserver, and creator of the living world. So far as vegetable life is concerned, the most important work in

LIFE'S HARDEST BATTLEFIELD—THE SLUM

THE AIRLESS, SUNLESS COURTS WHERE THE MICROBES OF DISEASE DESTROY HUMAN LIFE

this direction now being done has its arena here in the United States, where Luther Burbank is producing new forms of fruit and vegetables, useful and pleasing to man. Here also, in large tracts of Arizona and elsewhere, distinguished botanists are working upon the problem of specific changes, transmissible according to the Mendelian law, and produced by modifications of parental environment and nurture.

Man's coming wonders — his constructions in the world of life

In England also these problems have proved so enthralling that they have taken Professor Bateson away from his chair at Cambridge, to devote almost all his time to the actual construction of new plant-organisms in the John Innes Horticultural Institution. What may we not expect when men of his type — leaders in the world's scientific thought — are devoting themselves to practical experiments with a direct bearing on the food supply of future generations?

We are only at the very beginning of things; and if we attempt to limit what shall be possible we shall surely be made to look foolish by the event, as similar prophets have been in the past. But it is certain that all the material constructions of man, his bridges and railways, and houses and canals and dams, will pass into insignificance when compared with his coming achievements of construction in the world of life. The laws which obtain in the realms of physics and chemistry can be applied in the living world; and as the mind in life has used them ever since life began, so the mind in the form of life called man can use them now. Other forms of life have always contented themselves with achieving adaptation to the environment, non-living and living. Man transcends that achievement by first adapting himself to the environment, and then, his position being secure, modifies and reconstructs the environment to suit himself. Hitherto the most notable of his achievements have been in the non-living world, but we have already seen that the living neighbors of any living species are really the most important and influential part of its environment — as food or consumer, or anything between those extremes. Man is now proceeding to reconstruct the living environment and entourage by which he is surrounded.

Man's journey to the unknown with companion forms of life

No one can say what the results will be, but we can readily form a picture of a planet inhabited by man, and by a multitude of living species, animal and vegetable, new and old, which fill the earth with use and beauty for man, their master, director and, in many instances, their creator. This highest form of life is now engaged in grasping the scheme of things entire, and remodeling it nearer to his heart's desire. The directive powers of his intelligence cannot be limited. Thanks to it, his world is already a vastly different one from that in which his species was born, and it is being changed every day, less in the physical details of its surface than in the identity and numbers of the rest of the living world, who, like the dog in Maeterlinck's profound play "The Blue Bird", are to accompany and serve the children of men in their journey towards the unknown. In all these things we see, not the impending disasters wherewith faint-hearts so often seek to enshroud the final destiny of the children of men, but signs of an ever-brightening future.

SOME WINGED BEAUTIES

The Butterfly's Painted Splendor and
the Dragon-Fly's Shimmering Mail

THE SECRET OF THE FIREFLY'S RADIANCE

WHEN we look at the tousled fleece of a Southdown ram, and then at the radiant glory of a butterfly's wing, we have to admit that Mother Nature has not yet much to learn from the craft of man, her insurgent son, in the matter of wizard transformations of material. The wool of the sheep, the spines of the porcupine, the prickles of the hedgehog and the horn of the lusty rhinoceros are all cousins to the miracle on a butterfly's wing. The colors on a butterfly are derived from scales, which break and refract the light into the incomparable patterns that delight the eye. Spenser's was a beautiful conception of the rainbow mantle:

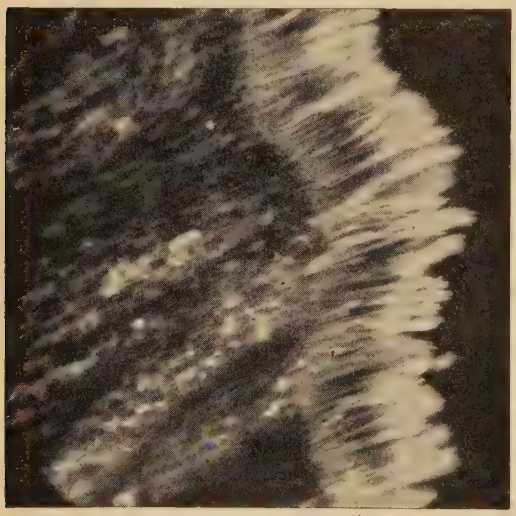
> The velvet nap which on his wings doth lie,
> The silken down, with which his back is dight;

but Linnæus forever fixed the definition when, finding that the "velvet nap" is really a series of minute scales, he called the order to which butterflies and moths belong Lepidoptera, or scale-winged.

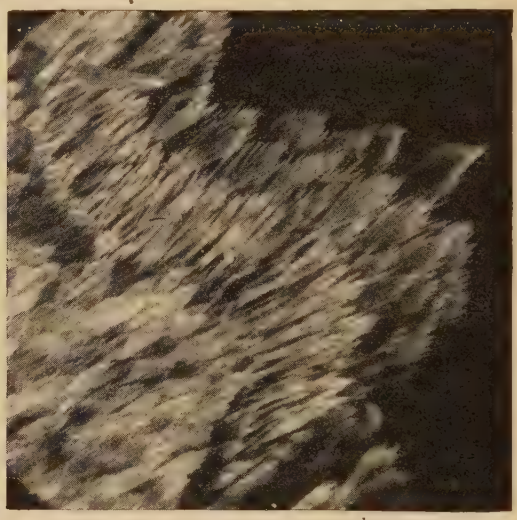
It was formerly believed that this sculptured mail served only the purpose of adornment, but there is more than that in these minute overlapping marvels. A rose without its perfume would be robbed of half its charm, and it doubles the interest in the butterfly to know that concealed among these tiny scales are exquisitely formed plumules which distil sweet scent. The presence of these specialized scales was known long before their purpose was clearly determined; and it remained for Dr. Frederick A. Dixey, of Wadham College, Oxford, to show how complicated is the system under which they discharge their functions. The scent-plumules are present only in the males of certain species, and in some are distributed generally over the surface of the wing, while in others they are collected into certain circumscribed areas. Dr. Dixey cites, as instances of the latter, the male of the common clouded yellow butterfly, and a tropical relative of the common brimstone butterfly. To these may be added examples such as the fritillaries, in which the scent-scales are placed on one or more of the middle nervules of the fore wing; the meadow-brown and its kindred, which have them on the disc of the fore wing; the skippers, which have these specialized scales in well-defined patches, but varying with species. Dr. Dixey finds that these scent-tracts are in many cases furnished with a supply of ramifying trachæa, microscopic air-vessels, derived from larger air-vessels running in the so-called veins or nervules of the wings. On reaching the scent-patches the main air-bearing trunks break up into minute branches, where it is conjectured they serve forcibly to disperse the scent through the scales into the outer air. Let us, however, consider more in detail the life-history of these remarkable insects, with which we open our chapter on some of the winged beauties that gladden the eyes of mortals.

The first stage is, of course, that in which the embryo develops within the egg. The eggs of moths and butterflies are among the most beautiful of all eggs, exquisitely shaped and colored, some distinguished by the most delicate of shades, others gleaming opalescent. Certain naturalists seek to establish a system of classification by the eggs alone, but the scheme

is unsatisfactory. The eggs are deposited by the parent insect upon the leaf of plant or tree which will constitute the food of its larvæ. This is one of the most striking triumphs of instinct. The larvæ are strong-jawed devourers of tough vegetable food, or, in the case of the clothes-moth caterpillar, of hair and woolen fabrics. The perfect insect when it feeds does so by a beautifully adapted suctorial proboscis and feeds entirely upon liquid substances. Yet every moth and every butterfly will, at the time of egg-laying, seek out the very plant upon which it is natural for the larvæ of its species to feed. The offspring never see their parents, the parents do not see their offspring, yet here is this invariable law in operation, this unfailing choice of the very food supply in which the caterpillar should be cradled.



THE EDGE OF A BUTTERFLY'S WING



THE TIP OF A BROWN MOTH'S WING

Be it noted that whereas the majority of caterpillars, taken when they emerge from the egg, can be reared upon practically any non-poisonous leaves, very few caterpillars, once they have begun their career upon a certain form of food, can be induced to change it. Most of them will die of starvation rather than submit to a change of diet. The moth or butterfly which has been reared from the egg in captivity upon a food different from that which the members of its species naturally take will, when liberated and mated, seek its nursery in a vegetable growth similar to that upon which its parents hatched. The eggs are placed, then, in such a situation that, at the appointed time, the larvæ, upon emerging, will find themselves surrounded by food — home and food, indeed, are one.

Hatching from so tiny an egg, the caterpillar, a mere tiny streak of life, naturally contains only small reserves of food supply; and the first thing it does, after recovering from the stress of bursting from its cradle, is to eat the latter. So small are the newly hatched caterpillars that, as they lie quiescent upon the shells of the eggs they have left, the observer requires a magnifying glass to assure himself that it is life, and not the discoloration of the eggs, that he sees. But the small grub has brought well-developed jaws with it into the world; and, whether it be cradled on the tender leaves of the nettle, upon the foliage of a delicate plant, or upon the tough leaves of privet, those small but powerful jaws soon relieve the observer of doubt as to the life-force that impels them to their work. Like a horse of morbid appetite which eats its bed, or the parasite within the living flesh of its animal host, the little caterpillar devours its home. That home may be within the trunk of some stout tree; it matters not, the caterpillar gnaws the wood as easily as its cousin bites its way through a cabbage-leaf.

The caterpillar is a sort of Fat Boy Joe of insects; it lives to eat, but with better excuse than the ample hero of the Wardle household. From the day of its birth it has to accumulate food reserves, not only for its larval life, but for the life which follows its wondrous change from crawling thing of lowly life into the winged gem of the sunlight. The day is coming in which its jaws will vanish, and then no solid food can be taken. With this almost incessant feeding the caterpillar soon grows too big for its skin. It lapses into torpidity, then casts its skin and alimentary canal. The whole investing integument is sacrificed. The caterpillar must crawl out of its skin. It emerges by way of a slit at the back of the head, crawling through, and leaving behind the covering of head, body, legs and claspers. A weak and weary caterpillar issues, limp and flaccid, with jaws as soft as putty. It rests, exhausted; and as it rests, its mandibles harden, strength returns to the entire frame, and, with strength, appetite. Feeding is renewed, and another cycle of growth is begun.

The varying stages of growth alternate with successive moults. These may number but five, or they may reach twice that number. The transformation from the egg to the pupa stage may be completed within a month or six weeks, or, as in the case of the goat-moth (*Cossus ligniperda*), it may extend over three years, during the whole of which time the great, malodorous caterpillar is eating its way through the heart of a tree-trunk. An equally large caterpillar, that of the privet hawk-moth (*Sphinx lingustri*), which has a very much wider range of diet than its popular name implies, may run all its larval course during a summer, though it is to be surmised that only when it obtains a certain minimum food supply is its metamorphosis thus expeditiously effected, for it is by no means rare for the caterpillar to avoid the pupal stage until the following summer, while a great number may pass the winter in the chrysalis stage. The importance of diet to the life-history of the caterpillar was brought home to one observer by the following singular experience.

A fine example of tiger-moth, caught and carefully handled, deposited, on the sides of the box in which she was confined, 252 eggs; then, of course, died. The eggs hatched in the usual way, and the caterpillars, regularly fed, ran a normal course until the end of September. Then their

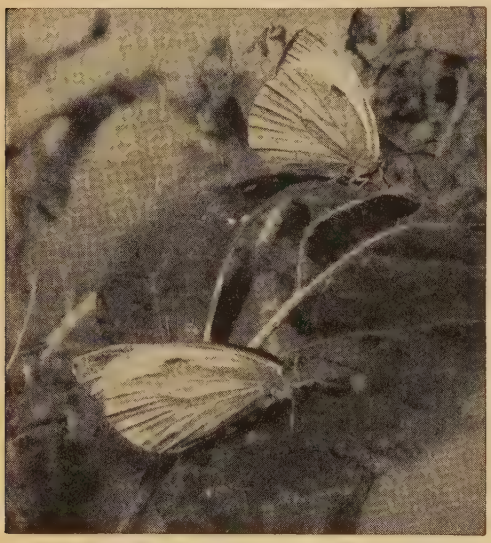
VAPORER MOTHS LAYING THEIR EGGS

Two wingless females are here seen resting on their cocoons, from which they have emerged, and depositing their eggs. They usually die among them. The males only are winged.

owner was absent for a fortnight, and their feeding was overlooked. After their fortnight's privation, the caterpillars appeared at first sight to be dead, but were not. They all refused to feed. They remained in this state of torpor for over two months, gradually becoming more and more attenuated and "wilted" in

appearance. At Christmas they seemed quite dried up, but food was offered them once more — tender leaves of lettuce grown under glass — and they began to feed again, after over two months of fasting! They fed all through the remainder of the winter; and as many as were allowed to complete their cycle reached the pupal condition, and emerged in due season resplendent moths. After an autumn fast, they had passed the winter in the caterpillar stage.

Proceeding, then, from the particular to the general, we may infer that when the caterpillar, which should become a chrysalis in a matter of a few weeks or



TWO WHITE, OR CABBAGE, BUTTERFLIES

months at most, remains in the larval condition for nearly a couple of years, such caterpillar has not, within the lesser time, stored sufficient energy to enable it to undergo the prodigious change which awaits the fully developed larva.

The alternating activity and quiescence of the caterpillar — the voracious feeding followed by the lassitude and enfeebled condition associated with the casting of the skin, are a prophecy of the pupal stage. But the change effected is very different. What kind of creature is it which sloughs its skin in order that a newer one may enclose its expanding frame? It is composed of thirteen segments, of which the head is one.

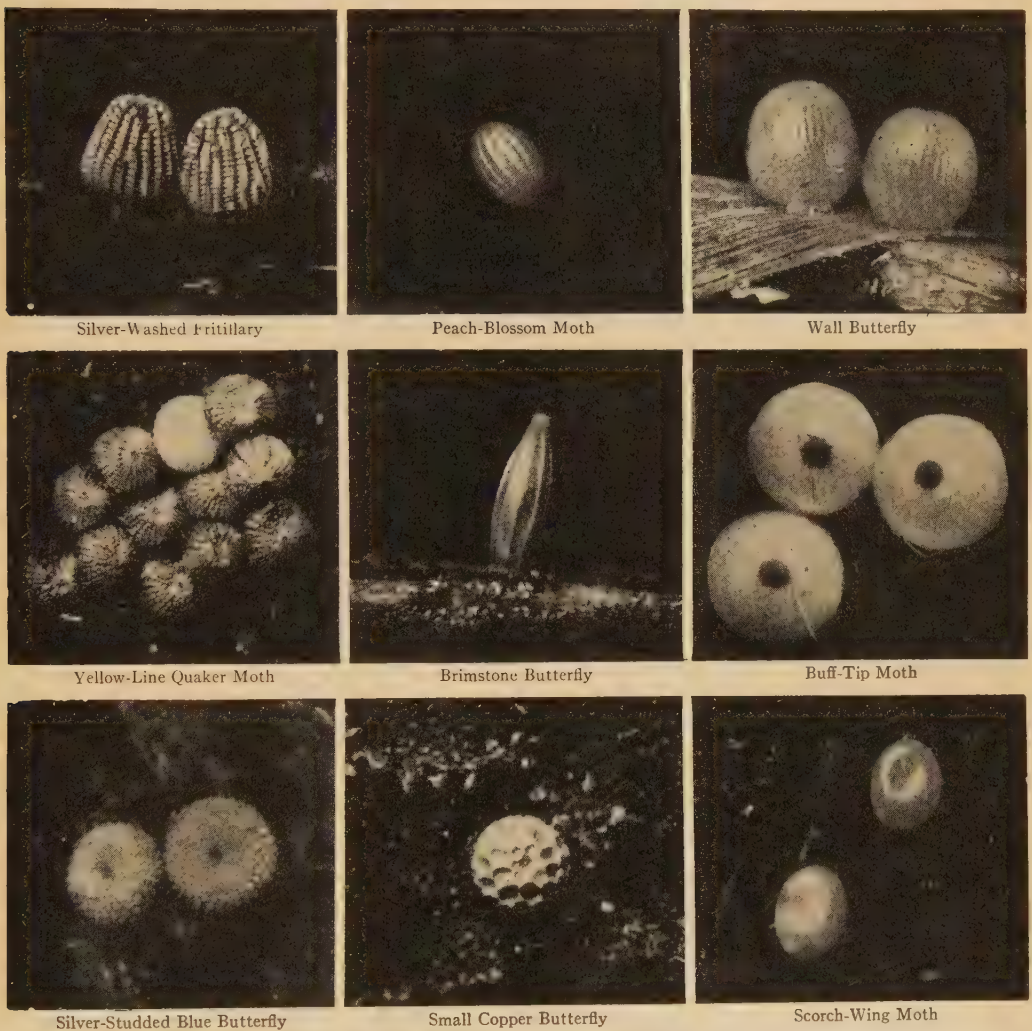
Its skin may either be smootn, or hairy or spiny. The three segments immediately behind the head are each furnished with a pair of true legs. These three segments correspond with the thorax of the perfect insect, from which will grow the three pairs of legs and the two pairs of wings. The remainder of the larval body corresponds with the abdomen of the adult, and is equipped, as a rule, with four pairs of false legs — pro-legs, as they are called — and a pair at the rear, which act as claspers. The sequence and number of the pro-legs are varied in the larvæ of the geometrician-moth. This caterpillar, which is known as the "surveyor" and as the span-worm, has but two pairs of pro-legs, so that, instead of progressing with the undulating motion of the ordinary caterpillar, it arches its body; then, gripping by the claspers and pro-legs, throws the forepart ahead, holds by the true legs, and finally draws up the hind part.

A succession of tiny orifices may be detected along the two sides of the caterpillar. These are the spiracles, the small breathing-tubes, and are the only external organs which reappear in the adult insect. By means of these spiracles, air is admitted to every part of the body. They reappear in the chrysalis, along whose chitinous sides they are more clearly perceptible. If the moth is to emerge from the chrysalis it is necessary that these spiracles should be carefully guarded.

One observer once lost a very fine specimen through placing a chrysalis in a box of bran for the winter with a number of meal-worms. The latter reduced much of the bran to a fine powder, which clogged the spiracles of the chrysalis, and caused the moth to die within its shell.

The head of the caterpillar is a complicated mechanism. It is furnished with small antennæ and minute palpi — delicate tactile organs which are probably of greater importance to the caterpillar than its eyes, whose power of vision is small. The jaws or mandibles are powerful, and it is interesting to note that an industrious microscopist has discovered three pairs of breathing-spiracles here.

Beneath the jaws lies the spinneret, by means of which the caterpillar spins the silken threads with which to suspend or immure itself. It would fill an entire volume larger than this one to describe the many different forms assumed by caterpillars of various species, their habits in life and in preparation for pupation.



Silver-Washed Fritillary | Peach-Blossom Moth | Wall Butterfly

Yellow-Line Quaker Moth | Brimstone Butterfly | Buff-Tip Moth

Silver-Studded Blue Butterfly | Small Copper Butterfly | Scorch-Wing Moth

THE BEAUTIES OF THE EGGS OF MOTHS AND BUTTERFLIES AS SEEN UNDER THE MICROSCOPE

Many of them are vividly colored and beautiful — the delicate green ground and lateral whites and heliotropes of some of the hawk-moth caterpillars are exquisite; and though the coloring is conspicuous enough when one holds the caterpillar on his hand, it harmonizes so well with the insect's surroundings that the larvæ are difficult to find, even in places where one knows them to abound. The hairy covering of the woolly bears, especially in the case of the fox-moth, is a most effective protection. These hairs are easily detached, and cause intense irritation to the flesh with which they come in contact. The hairs act as shock-absorbers, as the automobilist would say, protecting the caterpillar from injury when it falls, and they warn off practically all birds but cuckoos. The protective devices of caterpillars are deeply interesting and significant. Some species, like the larva of the goat-moth already mentioned, emit a foul odor when menaced; others, such as

the caterpillar of the puss-moth, eject formic acid from an orifice on the under side of the segment immediately behind the head. At a distance of two feet, this caterpillar is able to cause temporary blindness in a victim, while so virulent is the poison that it will cause the skin to blister and peel. Here, then, in these two genera, we have the defensive scheme in miniature of the porcupine, or, better still, of that handsome cactus the *Opuntia microdasys*, and of the spitting-snake.

Another defensive device is what is not inaptly called the "terrifying attitude" of certain caterpillars. Take the caterpillars of the Dicranura genus, to which the

THE FURRY CATERPILLARS OF THE PALE TUSSOCK MOTH

puss and kitten-moths belong. These caterpillars lack the anal claspers, or, rather, these are modified into extraordinary, tube-like members, from each of which at will a thread-like filament is shot out. While these are at once extruded and angrily waved if the caterpillar be touched, the fore part of the body is raised, so that the whole appearance is repulsive and disconcerting in the extreme. Caterpillars of hawk moths are armed with a horny, recurved appendage over the rear segments, and the threatened larva, holding fast by the legs, swings the hind part of its body with strength and rapidity. That suffices to frighten the timorous.

There is infinite gradation in the matter of protective resemblance to surroundings. Some caterpillars, when they come to rest, cannot be distinguished from twigs or thorns. The curator of the Sarawak Museum in Borneo has described a small caterpillar of that island that is not content passively to recline amid surroundings which it has come to resemble. Living among the branches of a spiræa-like plant, which at certain seasons is covered with numerous pale green buds, the caterpillar, normally distinguished by a profusion of small, spiny processes, bites off some of the buds, and, by means of its silk, fastens them to its spines, so that it looks exactly like one of the branchlets of the plant. When these transplanted buds wither, the caterpillar discards and replaces them with fresh ones. The same variety and suggestion of discrimination occur in the choice of abode for the pupa stage.

Butterfly larvæ, content as a rule with a mere twist of silk round the middle or from one end, seem to trust more to luck than the larvæ of moths, some of which furnish themselves with extraordinarily complex little citadels. Some seek refuge in the ground, some construct tunnels of silk within the trunks of trees and between the upper and lower surface of leaves; some fashion elaborate tunnels which admit of egress but not of ingress; some content themselves with cocoons of their own silk, fortified, in the case of woolly bears, with their bristles; and others, again, like the larvæ of the hawk-moths, will disintegrate even such unpromising material as wood or sandstone, glue the particles together, and fashion the material into an impregnable fortress. Most remarkable of all, perhaps, is the act of an African moth of the genus Nyctemera, which, before turning into a chrysalis, secretes and covers itself with a mass of bubbles — a most striking defense against insect-eating animals. It is not claimed by any thinking person that caterpillars reason, nor that butterflies and moths show anything higher than instinct, but M. Auguste Forel does not prove all that he attempts when he cites, as an evidence of absence of sensation in the caterpillar,

SOME WINGED BEAUTIES

PAPILIO TELEGONUS ♂ AND ORNITHOPTERA BROOKEANA ♂

NECYRIA MANCO ♂ AND ANCYLURIS MELIBAEUS ♂ UNDERSIDE

the case of larvæ which, wounded at the rear, began to devour themselves, beginning behind. A captive monkey, in ill-health, eats its tail, and a sick parrot its own feathers, but no one suggests that these creatures are insensible to pain.

The pupal stage of butterfly or moth may last a few weeks; it may last throughout autumn and winter; it may even extend over two years. Eggs laid in spring or early summer mature rapidly; and the caterpillars, if of the quick-developing type, will pass through all their stages within from two to three months; but a late-summer batch of eggs from the same species will result in chrysalids which winter in passivity. By such means the continuity of the species is secured. The vast majority of moths and butterflies expire with the passing of summer. It is not true of quite all, for to some is given power to hibernate, a fact of which we have evidence upon a warm, sunny day in winter, when a butterfly, battered relic of by-gone summer, creeps from hiding and leaps into the sunlight, to fall a victim, as a rule, to the first insect-eating bird that happens to be on the wing in the same locality. But, whatever the reason, the process by which the perfect insect appears is the same. At the last moult the caterpillar resigns forever its outer skin, and lies before us, reddish-brown if it be a moth, golden if it be a butterfly — a legless mummy.

THE WOOD LEOPARD MOTH

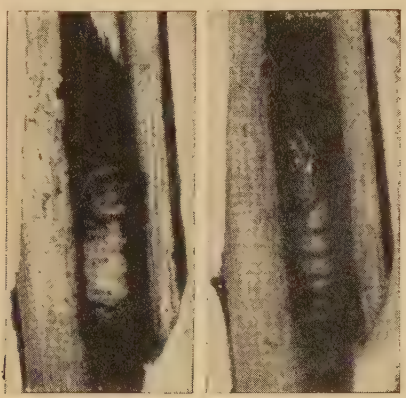
In due course the chitinous case becomes impressed with the shape within. We see the legs outlined, the eyes, the coiled proboscis. Throughout the long, cold months of winter this curious image remains inert, and you must hold it in your hand, or breathe warmth upon it, to induce a little wriggle to show that life is within. The great day of deliverance comes, the shell is fractured at the top, and a butterfly, limp and damp, crawls trembling out. That which entered the pupal stage as an awkward, creeping thing comes forth a crowning beauty of nature, so that one old-time enthusiast, who had patiently watched the process, declared it "the Resurrection painted before our eyes".

Four-winged, six-legged, endowed with powerful vision, here, if it be a butterfly, is the darling of the poet, like an animate fraction of the rainbow. Its wings at first are crumpled and limp, and we notice that the pattern for which we look is but dimly defined. The meaning of this has now been ascertained. The scales which give the butterfly its gorgeous colorings are there, but instead of lying flat and outspread as will presently happen, they are all upstanding, so that they may occupy the least space possible within the cocoon. Soon the wings unfold, blood courses into them from the main vessels of the body. This fluid is held to be fibrin in solution, the watery medium evaporating when the work of expansion

THE DEATH'S-HEAD MOTH

has been completed. According to Mayer, the fluid, if it lacked this fibrin, would cause the wings to become balloon-shaped bags. This is prevented by the action of the fibrin in holding the upper and lower walls together. This fibrin is derived, he states, from hypodermic cells that do not contribute to the formation of scales, but are stretched out from wall to wall of the wings.

The life of moth or butterfly may last but a few days, a few weeks, or months; exceptionally from one season to another. Generally speaking, however, it is brief. The butterfly, as a rule, knows but the joyous days of summer, when all the world is fair and smiling, and the air a bouquet of floral perfume. Its food is the nectar of flowers, taken by means of the suctorial proboscis.



THE LARVA AND PUPA OF A LEOPARD MOTH IN BEAN-STICKS

But even this structure may not be functional. Some of these creatures of the sunlight never eat or drink after emerging from the pupal stage. The females of some species of moth are wingless, and never leave the outside of the cocoon. The caterpillar has eaten meals enough for the butterfly. Trouvelot has shown that the larva of the Polyphemus moth consumes in fifty-six days 86,000 times its own weight in food and moisture — *i.e.*, three-quarters of a pound of oak-leaves and half an ounce of water. The caterpillar of the privet hawk-moth will eat, during a month of larval life, food aggregating over 11,000 times the weight at which it left the shell; while the caterpillar of the goat-moth, when it enters the pupal stage, is 27,000 times as heavy as when it quitted the egg.

The perfect insect, unless it be well provided for gathering the food from flowers, draws upon the reserves stored during the larval stage, as a queen-ant draws upon her reserves when setting up house and family.

It is impossible to enter into details as to the thousandfold varieties of butterflies and moths. Perhaps a word should be said as to the differences between the two sections of the order. There really is no set boundary. Moths, which are regarded as night-flying insects, as of course they are in the main, have many day-flying representatives. Where, as in parts of America, bats and other enemies of night-flying insects abound, nocturnal moths are rare. There are certain physical distinctions, however, to help us distinguish moths from butterflies. Each pair of the moth's wings is linked together by a unique hook-and-eye arrangement; moreover, the wings of moths are, as a rule, placed flat when the insect is at rest, whereas those of the butterfly are held in a vertical position. There is a difference, too, in the antennæ, those of the butterfly being club-tipped, while those of the moth are plain or "feathered". The main food of both is similar — the nectar of flowers. The white flower which gives off its sweetest scent in the evening is the banqueting hall of the moth when all the world but its immediate enemies is sleeping. Whether the moth takes carrion, we do not know, but some of the most beautiful butterflies will. The noble-looking Purple Emperor will stoop from his airy way above the tree-tops to a bait of putrid flesh upon the highway, just as the cabbage-leaf butterfly will seek its drink in a muddy puddle.

The protective devices of the Lepidoptera are as striking in the perfect insect as in the larva. The case of the kallima or dead-leaf butterfly of India comes instantly to mind, as does the mimicry of the hornet clear-wing of the true hornet, and the startling mimicry by edible forms of others of noxious flavor. Another well-known example is to be found in the privet hawk-moth caterpillar. Modern research in this direction has carried us far ahead of ancient conceptions. Professor Edward Poulton, indeed, has succeeded in showing that certain species of a distasteful group — the

A CYCLE OF INSECT LIFE

The caterpillar, the chrysalis, and the perfect insect of the swallow-tail butterfly.

Acræinæ — mimic other species of the same group, which are themselves mimics of the chief Acræine groups. On this is based the assertion that such forms of mimicry are not related to protective design. The disputants are as yet far from proving their case; and common belief is that an edible butterfly, which mimics an inedible species, and so avoids capture by bird or animal, has a better chance of perpetuating its line than the obviously edible insect which has the great disadvantage, in the struggle for existence, of lacking such protective resemblance.

With all their equipment of dissimulation and defense, larvæ of the Lepidoptera which reach the perfect insect stage are the exceptions. From egg to pupa they are exposed to manifold dangers. Birds, insectivorous animals and insects eat them by myriads; countless ichneumon flies assail them, deposit their eggs within them and leave them, living larders for the ichneumon grubs to devour alive. And no insect has more enemies than the adult moth or butterfly. Were this relentless war not constantly waged, caterpillars would, in the course of a few years, overspread the entire earth and devour every green thing that grows upon it.

The experience with the gypsy moth in New England defoliating all the trees within a comparatively few years after a few individuals escaped from captivity in Boston has taught us the melancholy truth of this statement.

LARVA OF DEATH'S-HEAD MOTH

LARVA OF PUSS MOTH

LARVA OF EYED HAWK-MOTH

Other winged beauties are the dragon-flies, so matchless in their special splendor that on suddenly being confronted with them in the north we cannot but fancy that they are wanderers drifted from sunnier skies. Yet, as all are aware who have the good fortune to live near inland waters, these resplendent insects are common enough, though not, of course, as to all the species.

Dragon-flies belong to the order Odonata, and have four membranous wings, finely netted with veins. The mouth parts are formed for biting, and formidable weapons they are. These forms are entirely carnivorous in the adult stage, and capture their prey (usually smaller insects) on the wing. So expert are they in this that they are known as the hawks of the insect world, and their manner of wheeling and veering over ponds in their search for food is called "hawking". Country folk have termed them "devil's darning needles", but the popular belief that they "sew up persons' ears" has no foundation whatever, and they are perfectly harmless to man. The colorings of these are brilliant as an artist's vision. Now, the larvæ of all these gems of beauty are grotesque-looking, flesh-eating creatures of the pond and lake. They have a remarkable instrument for the capture of their prey in the form of a pair of sharp pincers mounted at the extremity of a hinged or jointed under tip, which can be unfolded and shot out, to snatch an unsuspecting fish or insect swimming within range. The larva, hatched from an egg which is laid upon or under the water, or attached to the stalk of an aquatic plant, undergoes a succession of moults in the water, and reaches the final stage of its aquatic existence at the end of ten or twelve months; and then, climbing the stem of sedge or rush, affords the spectacle of which Tennyson sang:

A TIGER MOTH JUST EMERGED FROM ITS COCOON

> Today I saw a dragon-fly
> Come from the wells where he did lie.
> An inner impulse rent the veil
> Of his old husk; from head to tail
> Came out clear plates of sapphire mail.
> He dried his wings: like gauze they grew;
> Thro' crofts and pastures wet with dew
> A living flash of light he flew.

We find beauties of another order in the luminous insects. These are beautiful not because of their forms but because of their product. The fireflies and the glow-worms are simply misnamed beetles, not to be distinguished for any grace of outline; but, when the day is done, and all colors are put out by the darkness, then they light their wondrous lamps, the glow-worms to illuminate bank and sward and hedgerow, the fireflies to kindle their native woods with darting showers of radiance. A dance of fireflies in the sable night of a subtropical forest is a scene of beauty such as makes a man hold his breath in sheer delight and wonder. The stars seem to have swum from the heavens to dance a measure upon earth. In the tropical lands men light their path through trackless forest with fireflies gummed to a stick and carried aloft as torches; while native beauties imprison in their hair these winged stars of the woodland — ornaments more exquisite and more wonderful than any fashioned by the art of man.

We do not yet know definitely the secret of the source of light of the glow-worm and the firefly. Luminosity is not quite restricted to these; certain click-beetles, of which the fireflies are close allies, also have this special gift. These lowly beetles kindle their lamps without heat and without obvious labor. Two observers at work on the subject in India upon putting a firefly of the genus Luciola into a glass tube,

were struck by the resemblance of the green fluorescence of the light to that of the Crookes tube. Could this light, they asked themselves, be akin to the X-rays? They tried a number of experiments, and found that the light of the firefly penetrates wood, leather, flesh and black paper, and imprints itself upon a photographic plate fixed beyond these obstacles. The insect light was found to approach lamplight in the intensity of its effect on the photographic plate, even when the different media opaque to ordinary light were interposed between the two. The light cannot, therefore, be taken as phosphorescent, say these observers. "It may be premature to conclude that some of the rays emitted by the insect are X-rays, but it may be safely asserted that these rays are at least similar to X-rays and ultra-violet light in so far as they render certain opaque media transparent, and are intercepted by glass."

THE BEAUTIFUL DRAGON-FLY

How the theory would have interested the late Professor Langley! He passed many a fascinating hour in studying the great Cuban firefly (*Papophorus noctilucus*) seeking its secret by the aid of the refined measurements of the bolometer — which records a change in temperature of one-millionth of a degree — and by the aid of the spectroscope. After some study he says: "The insect-spectrum is lacking in rays of red luminosity and presumably in the infra-red rays, usually of relatively great heat, so that it seems possible that we have here light without heat."

Superlative beauty of radiance without heat results from the emanations of these lowly insects, a mystery as challenging as the discharges from the cells of the electric-fish. Light without heat from an insect — when the production of artificial light by man's contrivance involves the expenditure of from fifty to a hundred times as much wasteful and injurious heat as the illumination gained! If man by mechanism could imitate the light production of insects we should deem it a miracle. The firefly and the glow-worm are to us merely scintillating points of beauty in night's dark canopy. But what complete efficiency they represent!

The dragon-fly gets his name from his fierce preying on small insects. He is sometimes called "horse stinger," but does not sting horses. Born in water, he lives in air. On the left is a dragon-fly grub feeding on an insect; next, to the right, a dragon-fly is shown emerging from its grub-skin. In the center and on the extreme right the full-grown adult is seen.

THE *TERRA NOVA* ICEBOUND IN THE ANTARCTIC SEAS

THE DEPARTURE OF THE *NIMROD* WITH LIEUTENANT SHACKLETON'S ANTARCTIC EXPEDITION

EXPLORERS VII

NIKOLAI MIKHAILOVICH PRZHEVALSKI — EXPLORER OF CENTRAL ASIA
ANTONIO RAIMONDI — EXPLORER OF PERU
SIR WALTER RALEIGH — A FOUNDER OF THE BRITISH EMPIRE
SIR JAMES CLARK ROSS — DISCOVERER OF THE NORTH MAGNETIC POLE
SIR JOHN ROSS — A PIONEER OF THE NORTH WEST PASSAGE
ROBERT FALCON SCOTT — THE TRAGIC HERO OF THE SOUTH POLE
SIR ERNEST SHACKLETON — DISCOVERER OF THE SOUTH MAGNETIC POLE

NIKOLAI MIKHAILOVICH PRZHEVALSKI

The Greatest Explorer of Central Asia

IN spite of the extraordinary progress made by the nations of Europe in many directions in 1870, little was then known about the central regions of Asia. A number of men were ready to risk their lives in the icy wastes of the poles and the tropical jungles of Africa and South America, but no one seemed to care to follow the path through the enormous desert of Gobi taken by Marco Polo and his companions six hundred years before. Dim traditions of difficulties to which European travelers were unaccustomed no doubt kept back some men; political obstacles damped the ardor of other adventurers; and there were those who thought that the great cost and exceeding peril of exploring the vast, strange wilderness would not be repaid by any results of importance.

As a matter of fact, the expense of the famous expedition that rolled back the curtains of mystery and terror from Central Asia was less than $125! It was undertaken by a young officer in the Russian army, who merely set out with a couple of companions in search of sport. Happily, he was a first-rate geographer as well as an enthusiastic hunter. Getting well into the sea of sand in pursuit of new game, he found that with courage and endurance a white man could make his way from oasis to oasis as safely as a native tribesman. So he stayed there for thirty-four months, covered 7320 miles, and accomplished the most remarkable journey through Asia in modern times.

If it were not for the difficulty of pronouncing his name, Nikolai Mikhailovich Przhevalski would be as world-famous as Livingstone or Stanley. He is, indeed, the Stanley and Livingstone of Asia, one of the greatest explorers of all time. Even Sven Hedin merely followed where he led. He came of an old Cossack family settled at Kimbory in the government of Smolensk. Born on March 31, 1839, he lost his father at an early age, and was taught by his mother. As a boy he hunted in the forests of Smolensk, and there acquired that passion for sport that afterwards made him an explorer. As a Cossack noble he was born to a military career, and at sixteen he became a subaltern, and next year an officer. Entering the academy of the general staff, he took up the study of geography, and distinguished himself by a dissertation on the Amur region, the scene at that time of the rapid and continuous forward movement in Russian expansion.

He naturally hoped that his work would lead to his being sent to the land of adventure he had especially studied. But to his disappointment he was made a teacher of geography at a military school at Warsaw. But this apparent check to his ambitions was a fortunate thing. His new field of work made a man of science of him, and gave him the training and the knowledge necessary in his future exploring expeditions. At last, in 1867, he was given a position on the general army staff, and sent to Irkutsk, and he began the great work of his life, by exploring the Usuri, a southern tributary of the Amur. Then in November, 1870, he set out on the hunting

raid that brought him all the adventure he longed for, and more fame than he ever dreamed of. He roamed from Pekin to Tibet, crossing the desert of Gobi twice, discovering the wild camel amid the waste of sands, and the wild yak among the mountains of northern Tibet. He reached the source of the Yang-tse-Kiang, and was within a month's march of Lhasa, when the condition of his camels and the state of his funds compelled him to return.

In 1876 he struck out from Russian territory into the terrible Takla-makan waste. This is really the western extension of Gobi, but it is much worse than the larger and more famous of Asian deserts. It is a region of death — a sea of huge sand-waves in which not a gnat can live for want of water. Following the River Tarim, that skirts the northern edge of the lonely wilderness, Przhevalski came to a wide marshy lake where all the water ended. It was the ancient and mysterious Lob-nor, the lake seen by no European since Marco Polo. Century by century it has grown salter and smaller, and it is now a marsh, that strangely changes its position, rather than a body of water. For thousands of years the rise and fall of the water in this strange, withdrawn desert lake formed the pulse of the world. For at each fall the thirsty, starving tribes of Central Asia migrated, and fell in wild, fierce, predatory hordes on the civilizations of the Eastern and Western world.

On his third expedition, in 1879, the Russian explorer found the wild horse in the desert of Dzungaria, a kind of outlying arm of the great Gobi. He also came across more wild camels. Among the other new animals he found in the course of his explorations were an unknown variety of antelope and a new kind of sheep, while the wild yak was often met by him. In his third journey he collected 4500 birds, fishes and mammals, and 6000 insects. On this occasion he traveled 14,700 miles. He crossed the western Gobi, explored southern Tsaiden and Mongolia, and marched on Lhasa. But when he was within 170 miles of the Holy City of Buddhism he was turned back by the lamas.

His last expedition set out in 1883 from Urga. Crossing the Gobi in its wildest part, he turned southward in 1884, and reached the sources of the Hoang-ho in a region known to Chinese geographers as the "Sea of Stars." It lies among the mountains on the northeast of the Tibetan tableland — a tussocky marshland dotted with small lakes, and showing signs of having once been the bed of an inland sea. It was the first time that a European had seen this remote and secluded country. Przhevalski then went back to the Lob-nor Desert, and completed his earlier survey of the strange, vanishing sea. He returned west by the desolate Kuen Lun mountain range, and struck into the Takla-makan wilderness at Khotan, and discovered a double row of heights in this terrible desert. Raised to the rank of general by the Russian government, and honored by learned societies throughout the civilized world, Przhevalski began his fifth journey in the autumn of 1888, intending to penetrate to Lhasa, but died at Karakol on October 20, 1888.

ANTONIO RAIMONDI
A Modern Explorer of Peru

UNTIL quite recently more than half of the territory of Peru was unknown land. Consisting of wild, mountainous country, stretching eastward from the lower slopes of the Andes, its dense primeval forests shut out the forces of civilization. The forest had stayed the power of the ancient Incas; it had resisted the Spanish colonists, and at the middle of the nineteenth century it was sparsely peopled by bands of Indians, and as mysterious as Central Africa.

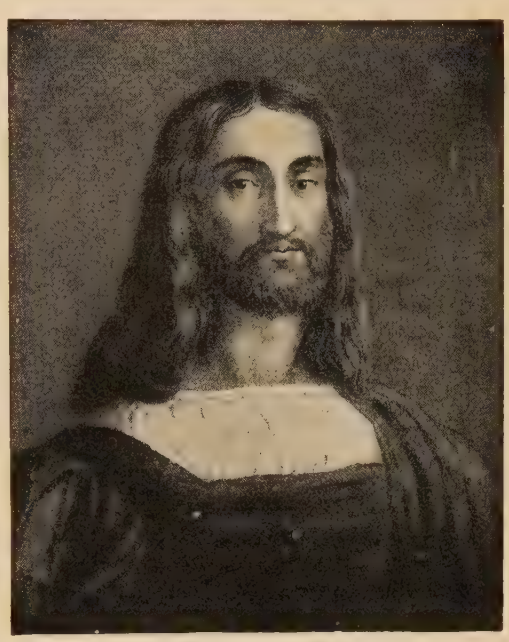
The Peruvians had no passion for exploration; they were busy enriching themselves by the exploitation of the resources of the coast lands. It was an exile from Italy, one Antonio Raimondi, who took up the task of discovering regions of Peru that had remained unknown from the dawn of civilization. Born in Milan, in 1826, Raimondi in his youth studied medicine and various branches of science, and threw himself eagerly into all the patriotic movements by which the Lombards sought to free themselves from the yoke of Austria.

But after the disastrous battle of Novaro, in 1849, he joined the stream of Italian refugees who settled in South America. His distinguished gifts were appreciated by the Peruvians, and he was made professor of medicine at Lima, and for twenty years he also occupied the chair of natural history there. In intervals of leisure between his work of teaching he studied the geology, geography and natural history of his second fatherland, and thus prepared himself for the great achievement of his life — the scientific exploration of the large unknown tracts of land in Peru.

He began in the province of Caraway, renowned for its gold-mines. Traveling on foot, he mapped out the various streams descending from the Cordillera Nevada. No one at that time knew in what direction these waters flowed, or what tributary of the Amazon they swelled. In each of the deep gorges through which he adventured Raimondi found distinct and peculiar kinds of birds, insects and shells, showing that in these lonely gashes in the mountains the evolution of life had proceeded for ages on new lines. He proved, in fact, that mere isolation was an important factor in the evolution of species.

After mounting from the tropics to the snows, he crossed the Andes, and descended to the steaming heat of the lower slopes. So thick was the growth of palms, tree-ferns and trees that in places the explorer walked in darkness, though the sun was blazing in tropical splendor on the matted roof of foliage above his head. Here began the extraordinary forest of South America, stretching without a break from the Andes to the Atlantic. A much-dreaded tribe of savages — the Chuncos — roamed the strange twilight land. After studying the Peruvian portion of the Amazon, Raimondi, in 1866, turned southward and investigated some of the chief tributaries of the Ucayali. He found that even in the dry season small steamers could go 1022 miles from the mouth of the Ucayali.

Owing largely to the fine pioneer work of Raimondi, the Peruvian government began to encourage explorers to adventure into the great forest, in the hope that they would discover a short commercial route to Europe by way of the Amazon and the Atlantic. Raimondi himself was able to give more time to collecting and arranging the materials he and other men discovered. His own explorations and researches covered almost every part of the republic, and out of them he began to build a monumental work, entitled "El Peru". But during the war between Chili and Peru large portions of his manuscripts were destroyed, and when he died, on November 1, 1890, only the first three volumes had been published.



ANTONIO RAIMONDI

SIR WALTER RALEIGH

A Founder of the British Empire

SIR WALTER RALEIGH, whom Dean Stanley termed "the father of the United States," and who certainly was a founder of the British Empire overseas, was born at Hayes, near Budleigh Salterton, in South Devonshire, England, in, it is believed, 1552. His father, head of an ancient house, which was connected with many distinguished Devon and Cornwall families, had married, as his third wife, Katherine, daughter of Sir Philip Champernowne of Modbury. She was already a widow, and mother of Humphrey and Adrian Gilbert, who were thus stepbrothers to Raleigh.

The name of Raleigh, by the way, is known to have been written in some seventy different ways. The popular spelling, which is here adopted, is said never to have been used by Sir Walter.

As a boy, Raleigh was devoted to literature, as indeed he was all his life, but there is historic foundation for the charming picture of Millais, which is shown on page 3482, which represents him sitting, as a handsome lad, listening with rapt attention to the story of some hardy adventurer who had returned from distant voyages overseas, who had to tell of strange waters so thick with fish as to impede the progress of the little, half-decked ships in which Englishmen went bravely out to face the dangers of lands seamed with gold and silver, whence the wicked king of Spain derived his wealth, and of many a stirring adventure beyond that wondrous Western Ocean.

The spirit of adventure leaped up in the heart of the boy, and he had barely passed through Oxford when, at seventeen, he was off to the wars in France and he accompanied Sir Humphrey Gilbert's unsuccessful expedition of 1578, an expedition nominally for the purpose of exploration but in reality a privateering adventure. He first becomes an important figure to us when he appears in Ireland in command of a troop sent to help put down the rebellion raised by the emissaries of Spain. He assisted gallantly at the capture of the fort, and took part in the proceedings in which the garrison, to the number of six hundred, were put to the sword. The presence of this hostile force in Ireland, when England and Spain were at peace, affords an interesting sidelight upon the actual relations between the two countries, and explains, as no argument could, how it was that Drake and Frobisher, and Raleigh himself when at sea, behaved as pirates. This Spanish garrison in Ireland consisted of pirates, and the history of their foray may well be read in conjunction with the reply made by Elizabeth (in the life of Drake) to the Spanish ambassador's complaint after the return of Drake from his circumnavigation of the globe.

The story told by old Fuller of Raleigh's introduction to Queen Elizabeth, of his spreading his gorgeous cloak to guard her from the mud is, to vary a Scotch verdict, "not disproven". But, whatever the fact as to his introduction, there is no doubt as to the high position in the esteem of that susceptible sovereign to which he at once advanced. He presented a splendid figure, with his dark hair and fine color, and his graceful, lofty bearing. He was renowned for valor and high courage as well as for prudent counsel; and these qualities, with his wit and eloquence, allied to a facile and graceful pen, made him the beau-ideal of a courtier. Elizabeth heaped honors and emoluments upon him, made him captain of her guard, gave him great estates in England and Ireland and presented him with rich monopolies. But she kept him ever near her person, and would not allow him to undertake personally any of the oversea ventures he was constantly planning. If he could not go in person, he put money into the ventures of others. He had in this way a principal share in establishing the Newfoundland colony which cost Sir Humphrey Gilbert his life, and he himself sent out the expedition which surveyed, and in the Queen's name took possession of the territory which she herself named in her honor Virginia.

The story of that colony need not be recalled at this place. Raleigh spent £40,000 — at least a million and a quarter of our money today — upon the scheme, and did not live to witness its success. But he had given England an idea and an ideal — that of a Britain beyond the seas. Since Raleigh's day the British Empire has increased by over eleven million square miles, but the colony that he founded was one of the first territories over which the English flag ever flew other than the impossible provinces the English once held in Europe. Calais, their last stronghold on the Continent, passed from them with the reign of Mary; in the reign that followed they colonized part of America by way of compensation, just as in later days they were to possess themselves of Australia in place of the lost United States, of which Raleigh was truly the father.

One of the material comforts that Raleigh derived from his enterprise resulted from the bringing home by his servant of the first potatoes and tobacco received in England. Drake, it is true, had brought some few leaves of the weed, but Raleigh smoked it, popularized it at court, and was, without doubt, drenched by his servant who entered his room to find his master, pipe in mouth, apparently on fire. Raleigh himself cultivated the potato on his Irish estate, so bestowing an inestimable gift on Ireland. The first English potatoes seem to have been grown in the Strand, in the garden of Lord Burghley, to whom some were given by Raleigh.

Raleigh's next disaster arose from the discovery of his liaison with Bessy Throgmorton, one of the queen's beautiful maids-of-honor. Both the lovers were thrown into the Tower, where Raleigh was kept prisoner for four years, only regaining his liberty in order that he might safeguard a rich Spanish prize from the rapacity of his fellow Devonians upon its being taken into Dartmouth. He eventually married Bessy Throgmorton, but sailed to Guiana, explored Trinidad, and the Orinoco for some hundreds of miles, and returned with stirring stories of the tropical splendors of the scenes he had witnessed, and of inexhaustible stores of gold. He had a

SIR WALTER RALEIGH IN THE TOWER OF LONDON, AT WORK ON HIS HISTORY OF THE WORLD

A cloud now appeared upon Raleigh's horizon. A new star arose in the court firmament — Essex, bold, insolent, haughty; and he, gaining the place of the former favorite, caused his withdrawal to Ireland, where he was consoled by the friendship of Spenser, who in 1589 was introduced by Raleigh, restored to favor, to the presence of the queen. Raleigh took an active part in raising the country in anticipation of the Spanish Armada, but there is considerable doubt as to the part he actually played in the fighting. There never stepped a more valiant defender of his country than Raleigh, but there never was a more insistent queen to keep a gallant man at home. glorious part in the action against Cadiz, and in the expedition of 1597 against the same enemy at the island of Fayal, which Raleigh captured before his leader, Essex, arrived.

Raleigh was gradually restored to favor, sat in parliament, and nobly defended religious liberties. Macaulay's picture of him in his prime relates to a time slightly earlier than this, but it is worth recalling here as bringing into sharper contrast the scenes that were to follow: "Raleigh, the soldier, the sailor, the scholar, the courtier, the orator, the poet, the historian, the philosopher, whom we picture to ourselves sometimes reviewing the queen's guard,

sometimes giving chase to a Spanish galleon, then answering the chiefs of the country party in the House of Commons, then again murmuring one of his sweet love-songs too near the ears of her Highness's maids-of-honor, and soon after poring over the Talmud or collating Polybius with Livy." But dark clouds gathered about him with the accession of James I, whose mind was poisoned against him by the crafty Cecil and the faithless Lord Henry Howard. He was stripped of his offices and the bulk of his possessions, declared to have conspired to set Arabella Stuart on the throne, tried, found guilty and sentenced to death upon charges as baseless as ever imperiled the life of any man. In vain was Raleigh's noble and eloquent defense, a defense which caused Dudley Carleton, who was present, to say that when it began he would have gone a hundred miles to see Raleigh hanged, but ere it was closed he would have gone a thousand to save his life.

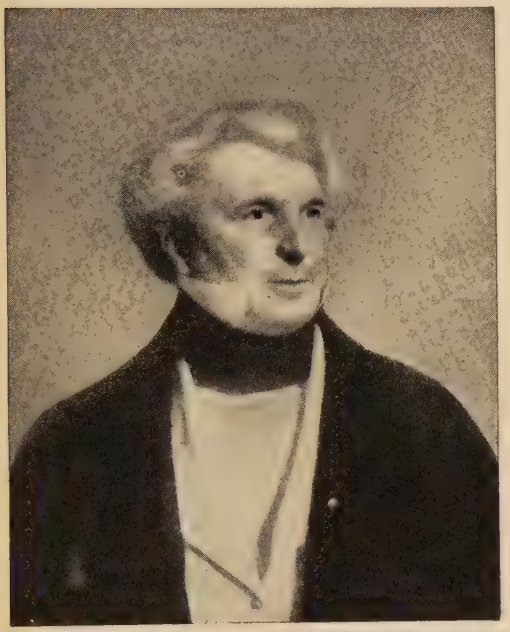
Raleigh was reprieved on the scaffold, but kept a prisoner in the Tower for fourteen years. There the only worthy member of the Stuart family, Prince Henry, visited him. "No man but my father would keep such a bird in such a cage", the amiable young Prince declared. For Prince Henry, Raleigh modeled a ship; for him he composed moral and political discourses, and began his noble "History of the World". Raleigh ceased the work with the death of the prince, and the "wisest fool in Christendom" stopped its sale, on the ground that it was "too saucy in censuring the acts of kings". Yet it only comes down to 130 B.C.! After fourteen years of imprisonment, during which the greatest scientists and wits of the age visited and cheered him, Raleigh was released to carry out another expedition to Guiana. The expedition was a failure. He did not discover his gold mine, though it existed and has since yielded millions. To compensate for his disappointment he sought to enrich himself, as was the custom, at the expense of a Spanish settlement. James was conciliating the traditional enemy, and made Raleigh's foray the pretext for putting into execution the death sentence passed fifteen years earlier. Raleigh accepted his doom with absolute composure and fortitude, and, reproved for his high spirits, said, "It is my last mirth in this world; do not grudge it to me." Raleigh was beheaded on October 29, 1618. To one who objected, as he knelt at the block, that he should lay his head towards the east, he replied, "What matter how the head lie, so the heart be right?" Than which no better epitaph could be found for him.

SIR JAMES CLARK ROSS
Discoverer of the North Magnetic Pole

ADMIRAL SIR JAMES CLARK ROSS was born in London on April 15, 1800, and at twelve years entered the navy under his uncle, Sir John Ross, the famous arctic explorer. For the next six years he was in various ships commanded by his uncle, and accompanied him on his first voyage in quest of the North West Passage, a stern beginning for a lad of eighteen. Little was done, but one of the company, William Edward Parry, who had joined as a volunteer, showed so much initiative, originality and independence of opinion that, upon his return, he was at once appointed to an independent command, and between 1819 and 1827 led four expeditions to the frigid North. Young Ross accompanied him on each trip. With Parry he reached the point at which waited a government reward of £5000 — for the first man to touch 110° west longitude of America, but under the same gallant commander he came to grief when their little vessel, the *Fury*, was smashed up by ice in Regent's Inlet. However, he was not born to die on that day.

He joined his uncle in the splendid expedition of 1829–33, being by this time promoted to the rank of commander of the little ship *Victory*, and, in a very fine bit of sledging work on the coasts of Boothia and King William Land, discovered, in 1831, the north magnetic pole. Two generations were to pass away before the south magnetic pole was located. Following this success, Ross was employed for three or four years upon the magnetic survey of Great Britain, and then, in 1839, began his successful work at the other side of the world.

Proceeding south, in 1839, in the ships *Erebus* and *Terror*, he crossed the Antarctic Circle in 1841, discovered and named Victoria Land, and in that region of eternal ice and snow found a mighty volcano in eruption, pouring forth molten lava and red-hot ashes from the fiery heart of a land in which the surface temperature never rises above freezing-point. Although Ross charted as rocks submerged ice over which the sea was breaking, and figured land where, as has since been found, land did not exist, his expedition gave a great impetus to antarctic exploration, and he well deserved the knighthood bestowed



SIR JAMES CLARK ROSS

upon him when he returned. In the same year, 1843, he married, and pledged himself to certain restrictions in the matter of further hazardous explorations. It was due to this pledge that he had to decline the leadership of the expedition in which Sir John Franklin afterwards perished. But whatever may have been the nature of his family undertaking, Ross went north once again, in 1848–9, in quest of the lost leader.

Ross, who rose to the rank of admiral, remained to the last a foremost authority in all matters of polar exploration. He was an inspired leader of men, and during the four years' trip to the South he lost but one of his company. Like his uncle, he made a miscalculation when he declared that the towering ice-cliffs of the antarctic continent would forever bar the way to the South Pole. Still, Ross reached 78° S., within 160 miles of the south magnetic pole, a fine achievement for a man whose equipment was limited by the methods of the first half of the last century. He died on April 3, 1862.

SIR JOHN ROSS

A Pioneer of the North West Passage

SIR JOHN ROSS, rear-admiral and arctic navigator, was born at Inch, Scotland, on June 24, 1777. He was entered for the navy at the age of nine, but, while keeping his name on the books of his first ship, bound himself apprentice on board a merchant vessel to gain experience. Returning to the navy at twenty-two, he fought with distinction in the war with France, being, it is said, thirteen times wounded. Although he rose to the rank of rear-admiral, he is of note today chiefly from his efforts to find the North West Passage.

His first expedition was undertaken, in 1818, in the whaler *Isabella*, accompanied by the *Alexander*, of which Parry, his subordinate, was in command. The order of the government was to find a North West Passage by way of Davis Strait and Lancaster Sound to Asia and the golden East. The route seems open and simple from that deceptive guide the common atlas, but never was key forged with such difficulty and suffering as that to this still impracticable channel. That men should wish to attempt the feat at all is in itself a remarkable tribute to the innate heroism of the race. All that men had experienced in the desolate wilds was of a character to make the average sailor wish to keep his toes warming before the fire at home; but the Rosses and the Parrys and the Franklins, the Cooks, the Davises and Baffins, were never happier than when pitting their daring and endurance against the terrible forces of nature in their most pitiless guise.

What was the nature of the challenge that these heroes accepted? Perhaps no more interesting picture could be suggested

than that which rises to the mind from the quaint title-page of the book of the doughty Dutchman Barents. It runs as follows: "The true and perfect description of three voyages so strange and woonderful that the like hath never been heard of before. Done and performed three yeares, one after the other, by the ships of Holland and Iceland, on the north sides of Norway, Muscovia and Tartaria, towards the kingdomes of Cathaia and China, showing the discoverie of the straights of Weigates, Nova Zembla, and the country lying under 80 deg., which is thought to be Greenland [it was Spitzbergen], where never any man had bin before; with the cruell beares and other monsters of the sea, and the unsupportable and extreme cold that is to be found in those places. And how that in the last voyage the shippe was so enclosed by the ice that it was left there. Whereby the men were forced to build a house in the cold and desart country of Nova Zembla, wherein they continued ten months together, and never saw nor heard of any man, in most greate cold and extreame miserie; and how after that, to save their lives, they were constrained to sail over 350 Dutch miles, which is above 1000 miles English, in little open boates along and over the maine seas, in most great daunger; and with extreme labour and unspeakable troubles and great hunger."

Ross sailed for Baffin's Bay in 1818, and explored it. The map of this part of the world is a permanent record of the perplexities and errors of the men who have sought to fill in its blank spaces, and Ross was destined to commit one of the strangest errors of all. Baffin's Bay is no bay; it is a sea, 800 miles long, with an average breadth of 280 miles, and is frozen from shore to shore for a considerable period of the year. It communicates, by way of Davis Strait, with the Atlantic, and, by way of Smith and Lancaster Sounds, with the Arctic Ocean. Ross found the people nearest the Pole, but he could find no northern outlet to the bay. He turned westward, therefore, into Lancaster Sound, which is one of the gateways of the North West Passage. And there one of those strange mistakes which have so often occurred in these high latitudes was made. Clouds or some form of mirage obscured the sound, and, misled by their singular appearance, Ross took them to be a huge range of mountains spread inexorably across his path. He put his ship about, and came home, to report Lancaster Sound a land-locked bay. His clouds he named the Croker Mountains, and fully described them in a narrative published in 1819.

Now, with him on the expedition were Parry and a young sailor scientist, Captain (afterwards Sir) Edward Sabine, whom we meet in the biography of Tyndall. Sabine was astronomer to the party, and, with Parry, was not convinced that the Croker Mountains had any existence outside the imagination of his leader. When Ross's work appeared, Sabine challenged the mountains, as Parry had already done. Parry, indeed, was so confident that the government had even now sent him out on a further expedition. This impeachment was a bitter humiliation to Ross, but it was all for the good of knowledge, for the way from the East to the West, from the New World to the Old, lies through the very sound which he declared to be barred and sealed by a mountain range. The very controversy thus provoked stimulated inquiry and exploration, and it was by Lancaster Sound, in the end, that Franklin and his comrades went to their doom.

Ross was at last convinced, and yearned to redeem himself, but not until 1829 did he get an opportunity, when, contributing $15,000 of his own, he was given command of the expedition fitted out mainly at the cost of Felix Booth. His vessel was the little *Victory*, notable as the first craft that ever attempted to steam through the North West Passage. Ericsson built her engines, and a strange story attaches to their failure. Ericsson knew Ross as a naval officer, and, the meaning of his mission being kept a secret from even the engineer, Ericsson thought the *Victory* would be manœuvering in home waters, whence she could easily reach him for alterations. He therefore put into her the first marine engines built below the water-line. He thought she was a little warship, and

treated her as such. The engines were a failure in the *Victory*, but they have since been successfully installed in every other warship in the world. Ross, keeping his own counsel, had the engines geared up to hopelessly unsuitable paddle-wheels, of which Ericsson knew nothing. He blamed Ericsson for the failure of the scheme, but the inventor retorted hotly that he had been deceived as to the purpose of the vessel, and that Ross's gearing and paddle-boxes were "a perfect specimen of ignorance of the laws which should be consulted in the construction of bodies intended to move through the water".

However, the first marine engines to go to the Far North remained there. Ross had them cast into the ocean; and in some post-glacial day they may be discovered at the bottom of an erstwhile frozen sea, to prove to an astonished world that the ancient Eskimos of the nineteenth century had advanced ideas on steam navigation. Mechanical propulsion failing, Ross trusted to wind and sails and the drifting of currents. He made no second mistake about Lancaster Sound, but failed to get beyond the ice into Barrow Strait, so turned southwest into Prince Regent's Inlet, and sought in vain to break through by that route. He was caught by the ice, and his ship imprisoned, during the winter of 1829–30, in Felix Harbor. The summer carried him only a few miles south, and the second winter was spent in Victoria Harbor. There the little vessel remained tightly held throughout the summer of 1831, and, of course, the winter of 1831–2. In May of 1832 Ross was compelled to abandon her, and march to Fury Beach, where his nephew and Parry had been wrecked in the expedition of 1824–5. The ruined *Fury* remained on shore, and from her timbers the party constructed a hut, and there spent their fourth successive winter in the ice. In the following summer they made their way on foot to Lancaster Sound, and to their joy found a whaler. It was Ross's old craft, the *Isabella*, in which he had made his first voyage to the North. In this the expedition returned, reaching England in October, 1833, after an absence of four years.

Although the voyage did not achieve the North West Passage, it was highly important in results. The Gulf and Land of Boothia, named in compliment to the London distiller who had financed the expedition, were thoroughly surveyed; King William Land was explored, and the younger Ross determined the position of the north magnetic pole. Ross had nobly atoned for the blunder of the Croker Mountains. He had laid useful foundations for Sir John Franklin; and when Franklin was lost, the valiant old hero, then threescore years and twelve, was the first to set out to seek him. In the teeth of the opposition of the Admiralty he fitted out a small vessel, named the *Felix*, from funds raised by public subscription and a grant from the Hudson's Bay Company. In May, 1850, he set out from Stranraer, and made his way to Lancaster Sound. He failed, however, to glean any tidings of the ill-starred party, and returned in the following year. He died in London on August 30, 1856. The one mistake of his career involved him in bitter controversies to the end of his days, bringing him into conflict with men whom he would not forgive, but his quarrels had the effect of keeping interest alive in the North West Passage, and of stimulating others to effort.

ROBERT FALCON SCOTT
The Tragic Hero of the South Pole

ROBERT FALCON SCOTT, the tragic hero of the South Pole, was born at Outlands, Devonport, England, on June 6, 1868. He entered the navy at thirteen, served as midshipman on the Cape station and elsewhere, and became acting sub-lieutenant in 1887. He received his commission as lieutenant two years later, when on the Pacific station, and in 1899 was torpedo lieutenant of the flagship of the Channel Squadron.

Captain Scott had no particular interest in polar exploration, and it was quite by chance that he became the leader of the *Discovery* expedition. Hearing accidentally in the early summer of 1899 that an Antarctic expedition was being formed, he wrote applying for the command of it, and a year afterwards he was appointed and promoted to the rank of commander.

The *Discovery* left London in July, 1901, and returned in 1904, having made more contributions to our knowledge of the Antarctic than had been made for sixty years. Going three hundred miles nearer to the South Pole than Ross had attained, Scott practically solved the problem of reaching the pole, for he discovered a route to it. Both Shackleton, who accompanied him in his sledge expedition farthest south in 1903, and Amundsen, who followed his path, were very greatly indebted to Scott's pioneering work.

Besides his great journey over the ice

Photo Thomson

ROBERT FALCON SCOTT

barrier, Scott greatly added to geographical science by striking westward through the mountain ranges of South Victoria Land, across the wild and terrible plateau. His work was recognized as one of the most important feats of exploration; and on his return honors were bestowed upon him by both British and foreign geographical societies. He was promoted to the rank of captain in the navy, and after writing a narrative of the expedition, published in 1905, he resumed his duties as a naval officer, and obtained a staff appointment in the Admiralty, which kept him for a time in London.

But the strange fascination of the bleak and terrible waste of ice around the South Pole worked on his mind. He had been nearly frozen to death; he had been overwhelmed by a blizzard for seven days. He was now honored by king and country, and married, and his feet were firmly set on the path to the highest positions in his profession, yet in his heart he longed for the perils and the agonies of life in the Antarctic. Only the difficulty of raising funds for a new expedition kept him amid the comforts and shelter of civilization.

In the meantime, Shackleton raised the money for another attack on the South Pole, and Scott waited to learn what his old companion in adventure had achieved. When Shackleton returned with the happy news that the pole was less than a hundred miles from the point he had attained, Scott yielded to the call that had been sounding in his heart ever since he returned from the ice barrier. He knew he had cleared the path, and he was eager to profit by his own work. With great difficulty he managed to borrow money for his second expedition; and after a government grant of £20,000 was promised, the explorer got to work on the practical details of his new expedition. The *Terra Nova*, a whaling barque of 749 tons, was purchased, and on it Scott and his band of heroes sailed for New Zealand on June 1, 1910.

McMurdo Sound was reached in December, and the main party landed and fixed their headquarters at Cape Evans. Ice prevented the second party from landing at King Edward VII Land, where Amundsen afterwards came on his dash to the pole. This second party, under Lieutenant Campbell, wintered in a hut on Victoria Land, and lived on seals. Their adventures and sufferings were heroic, but they managed to win through. A third party was placed on the west side of McMurdo Sound. Scott had taken with him a larger scientific staff than had ever before worked in the Antarctic, his aim being to solve some of the chief problems concerning the character and the history of the high lands around the South Pole. Eleven months were spent in scientific investigations, including the study of the upper air by means of balloons.

ALPINE DANGERS IN THE ANTARCTIC

A NARROW ESCAPE FROM DEATH IN CAPTAIN SCOTT'S FIRST ANTARCTIC EXPEDITION

In the meantime the work of laying depots for the march to the pole had been carried out, and on November 2, 1911, it was begun. Like Shackleton, Scott did his sledgework with ponies instead of dogs. Unfortunately, nearly half of them died before the march began, and Scott put off for a month his dash to the pole in order to save those remaining. This was one of the causes of disaster. At first all went well, and the last message received from the expedition told that the party were within one hundred and fifty miles of its goal. Here it was left by the second in command, Commander Evans; and while he was bringing back the news Scott pushed on southward.

With Scott were Dr. E. A. Wilson, the chief of the scientific staff; Captain L. E. G. Oates, who looked after the ponies and mules; Lieutenant H. R. Bowers, the commissariat officer of the party; and Petty-Officer Edgar Evans, who had served on Scott's first expedition. They reached the pole on January 18, 1912, in bitterly unfavorable weather, and the return journey became a dreadful struggle against death. Evans, an exceptionally strong man and a tried antarctic traveler, was the first to break down. He was so frost-bitten that his comrades had to help him along, and the delay in getting from one depot to another brought them all nearer to death. In February the enormous tract of ice of the Beardmore Glacier was reached. It was the obstacle that had stopped Scott on his first expedition, and it was now much rougher and extremely difficult to travel on. Evans fell, stunning himself and hurting his head, and died on February 17 at the foot of the glacier.

Here the weather, which had all along been bad, suddenly grew much worse. The wind rose to a tempest, and the temperature fell very low, robbing the explorers of their vitality. Captain Oates's feet and hands were badly frost-bitten, and, though he struggled on heroically, bearing intense suffering without complaint, he was at last absolutely unable to travel. On March 16 he went to sleep, hoping that he would not wake, for he saw that his weakness was bringing disaster on his comrades. In the morning it was blowing a blizzard outside the tent. Oates staggered out, saying: "I'm just going outside, and I may be some time." "We knew that Oates was walking to his death," said Scott, "but, though we tried to dissuade him, we knew that it was the act of a brave man and an English gentleman."

Oates was unable to travel, and his companions would not leave him. So he went out into the blizzard in search of the death for which he had been waiting and longing. Captain Scott, Dr. Wilson and Lieutenant Bowers sadly pushed northward against a high wind that drove the ice crystals like needles into their skin. With bowed heads and aching bodies they fought onward, but the blizzard was so overpowering that they had to creep under the shelter of their tent when only eleven miles from their next depot. They had fuel for one hot meal and food for two days, but the blizzard raged for more than a week. In spite of want of food and want of heat, Scott and his companions lived for four days; and with the coldness of death creeping over him the heroic explorer took out his diary and wrote his memorable account of the tragic expedition:

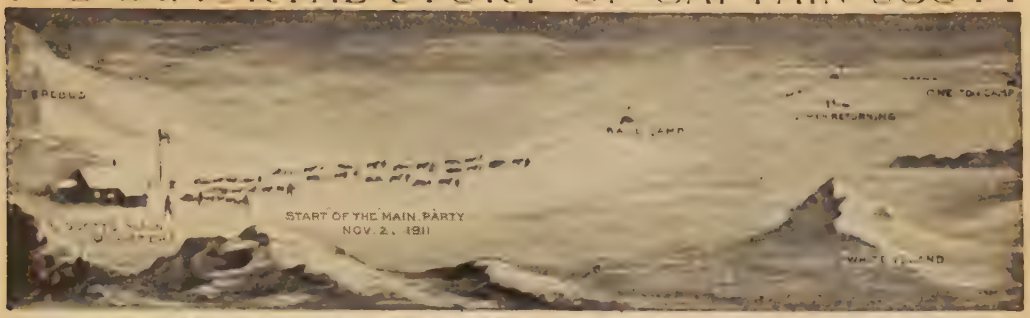
"I do not regret this journey, which has shown that Englishmen can endure hardships, help one another, and meet death with as great fortitude as even in the past. . . . We have been willing to give our lives for this enterprise, which is for the honor of our country.

"Had we lived, I should have had a tale to tell of the hardihood, endurance, and courage of my companions which would have stirred the heart of every Englishman. These rough notes and our dead bodies must tell the tale."

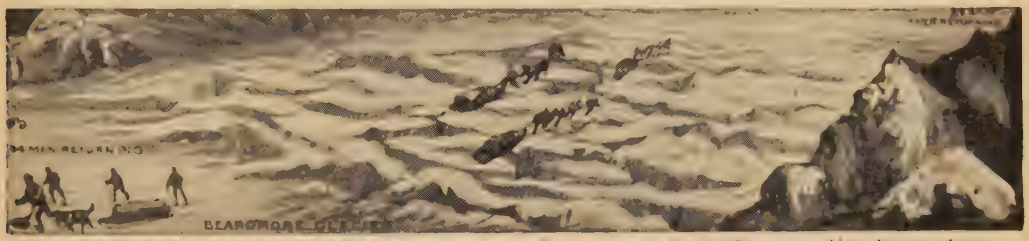
So died Captain Scott, Dr. Wilson and Lieutenant Bowers; and it was not until November, 1912, that their bodies were found. The account of the discovery of the South Pole and the subsequent disaster appeared in the posthumous "Scott's Last Expedition" (1913).

A bronze statue of the explorer, subscribed for by the officers of the navy and the work of Lady Scott, was erected in 1915 in London. It shows him in his arctic dress.

THE IMMORTAL STORY OF CAPTAIN SCOTT



The departure from their base of Captain Scott and his companions with dogs, ponies, and provisions, for their dash to the South Pole. The distance to One Ton camp was 100 miles



The difficult ascent of the Beardmore Glacier by a dozen men, seven of whom returned to the base on reaching the vast plateau on which the Pole is situated. Five men made the final dash

The party at the South Pole, which was reached on January 18, 1912. Here they found a letter from Captain Amundsen, who had arrived a month before. Captain Scott and his companions spent a day making observations

The first disasters on the homeward journey—the illness and death of Petty Officer Evans on the Beardmore Glacier, his burial at the foot of it, and the illness of Captain Oates

The heroic self-sacrifice of Captain Oates, who walked out into the blizzard to die. The short struggle onward of Captain Scott, Dr. Wilson, and Lieutenant Bowers, and the scene of their death in a tent but eleven miles from One Ton camp

SIR ERNEST HENRY SHACKLETON
Discoverer of the South Magnetic Pole

ERNEST HENRY SHACKLETON was born at Kilkee, in the South of Ireland, on February 15, 1874, the son of a physician, and educated at Dulwich College. He went to sea in the merchant service and later was lieutenant in the

Photo Dinham, Torquay
SIR ERNEST SHACKLETON

Naval Reserve. In 1901 he was third lieutenant of the antarctic expedition under Captain Scott, but he first became prominent internationally when he commanded that of 1907–09. It was he who collected the money to equip the *Nimrod* for the trip which succeeded in getting within 97 miles of the South Pole, up to then the point farthest south ever attained by man.

The expedition made a southern record of 88° 23′ and relocated the southern magnetic pole. Shackleton's party attempted to reach the pole by the same route which Captain Scott followed successfully in 1912. His was the first party of antarctic explorers to be assisted by ponies and motor transportation; although the ponies were eaten, the motor sledge was not used much and hand-power had to be depended on for most of the hard pulling.

Shackleton's most dramatic voyage was that of the transantarctic expedition of 1914–16, which he commanded. Previous to starting, Shackleton at the beginning of the war offered the services of his party to the British Admiralty, but was told to proceed with the voyage of exploration. The expedition started with the object of crossing the south polar continent from sea to sea, following the success of Scott and Amundsen in reaching the pole. Shackleton desired to cross from Coats Land to Ross Bay. Although he failed to do so, and although the geographical and other scientific results were small in comparison to previous voyages, the trip made an extraordinary story of adventure related in his book called "South". His ship, the *Endurance*, began to meet the ice at the beginning of December, 1914, off the island of South Georgia. The party traced the antarctic coast southwest from the place sighted by Bruce in Coats Land and joined it up with the land discovered by Filchner in 1912. On January 15, 1915, the vessel was caught in the ice of Wedell Sea off Caird Coast, in 76.34° S. She drifted north with the pack until November 14, when she was crushed and sank to the east of Graham Land.

The party continued to drift with the ice floes and endured many perils and hardships. On April 9, 1916, they launched their boats in 62° S. latitude. Six days later they landed on Elephant Island. In a few days a perilous attempt was made to reach South Georgia, 300 miles away, through snow blizzards and in a heavy sea, in a twenty-foot boat. Shackleton was accompanied in this venture by five men, the twenty-two other members of the party remaining on Elephant Island.

THE FROZEN WASTES OF THE ANTARCTIC

From Shackleton's *The Heart of the Antarctic*. © J. B. Lippincott Co.

These photographs of the South Polar ocean were taken by the Shackleton Expedition. At the top is a ship on the horizon, with numerous seals near the shore; below, an explorer is having a nearer view of the seals, the representatives of Life which were there before him.

After great trouble Shackleton and his companions reached an inlet in South Georgia on May 16. With two companions, he made another difficult journey across the mountainous and glacier-covered interior of South Georgia to the whaling station in Stromness Bay, on the northeast coast, which the *Endurance* had left in 1914.

Meantime, the twenty-two men marooned on Elephant Island were enduring even greater hardships than those of Shackleton and the five who had left. Three attempts to rescue them failed. Finally, after four and one-half months, Shackleton rescued them all in a Chilean tug.

Later Shackleton had to rescue seven other members of his expedition. They sailed on the *Aurora*, which was sent around to Cape Evans to wait on the opposite side of the antarctic continent until Shackleton and his men from the *Endurance* crossed. But on May 6, 1915, when Captain Æneas McIntosh and his nine men were ashore on the ice, the *Aurora* broke away and was carried off hundreds of miles by the ice. When she finally got free Commander Stenhouse, in command, was barely able to get her to New Zealand. Three of the ten marooned at Cape Evans died, but Shackleton rescued the seven survivors and took them to New Zealand.

Shackleton's last voyage was undertaken in the *Quest*, the smallest vessel in which he ever sailed. She was of wood, only 111 ft. long by 23 ft. beam, and of about 100 tons, net. She left England on September 17, 1921, and touched at various ports for repairs before leaving Rio de Janeiro for the island of South Georgia, which Shackleton was to have used as the jumping-off place for his trip into antarctic regions. But while anchored off the island, he died suddenly on board, on January 5, 1922, and was buried on this "gateway to the Antarctic".

The object of the expedition, which proceeded under the command of Captain Frank Wild, was not to try a spectacular dash for the South Pole, but to make a 30,000 miles voyage of oceanographic discovery, with scientific explorations and observations, among the little-known islands of the South Atlantic and South Pacific and the uncharted seas of the Antarctic. It was to have lasted two or three years. He had announced before leaving that he intended to make a coast-line voyage which he expected would add more to their knowledge of the Antarctic than isolated journeys into the interior. The vessel had wireless installation and a seaplane on board, but proved too small and crowded for comfort and, when she began to leak under the ice pressure, Wild returned without having accomplished all that he and Shackleton had hoped when first they set out from home.

Shackleton was knighted in 1909 for his distinguished services. The same year he was made a commander of the Victorian Order. He was a fellow of the Royal Geographical Society and the Royal Arts Society, a younger brother of Trinity House, which controls the pilotage and lighthouses, and a special gold medallist and silver medallist of the Royal Geographical Society.

He was the recipient of the King's Polar medal (two bars), and of medals from the geographical societies of Scotland, Denmark, Belgium, France, Antwerp, Italy, America, Paris and Russia. He was a commander of the orders of Danneborg of Denmark, Pole Star of Sweden, St. Olaf of Norway, officer of the Legion of Honor, Royal Crown of Prussia, Crown of Italy, St. Anne of Russia, etc. Besides "South", he had published "The Heart of the Antarctic" (Philadelphia, 1909) describing his expedition of 1907–09 and from which the illustrations on the previous page are taken, and "The Diary of a Troopship".

THE GREATEST MEN OF ALL

A Study of Genius, and the Foolish Fallacy
that Genius and Insanity are Closely Allied

THE CLEARER PRESENCE OF GOD MOST HIGH

WE must not leave the study of man as a whole without some attempt to appreciate those exceptional manifestations of humanity which we call genius, and which have often been regarded as superhuman, so far do they transcend the ordinary capacities of man. We do not believe that these manifestations are superhuman — unless, indeed, man himself be more than what we commonly look upon as human flesh. We regard them as specially salient cases of manhood, as showing, more clearly and completely than in ordinary cases, the true nature of man. Our study of his species would be absurdly inadequate if we took no cognizance of its highest and most perfect instances, in which the essence, the *differentia*, of man, as compared with all other forms of life, becomes most manifest. Perhaps we can indeed learn more of the true nature of man from these exceptions than from the more familiar instances.

There are those who think otherwise, and they have to be reckoned with. In the 19th century we find two notable men, vastly different in temper and training, who stand for diametrically opposed opinions of the nature of genius. Those men were Thomas Carlyle and Cesare Lombroso. To Carlyle's view and estimate of the man of genius we shall return in concluding this chapter; it is one of those portions of 19th century philosophy which are still fit for the third decade of the 20th. Lombroso's view must here be dealt with before we proceed to the chief question at issue, which is the psychology of genius, a question upon which a great student, Frederic W. H. Myers, has much enlightened us.

Lombroso's theory of genius was that it is a form and manifestation of insanity. This idea has gained great currency in a cynical age, when anything that belittles greatness is comfortable to the small. In connection with it we commonly hear quoted the poet's familiar couplet:

> Great wits are sure to madness near allied,
> And thin partitions do their bounds divide.

Lombroso's views expressed in his book "The Man of Genius", and in others, have been widely disseminated, thanks especially to his distinguished pupil Dr. Max Nordau, whose "Degeneration" has been one of the most read and discussed among quasi-scientific works of recent times. The public, not unnaturally, supposes that the opinions of authors so brilliant and positive are authoritative, and this view of genius is only too generally accepted as that really held by science.

It is nothing of the sort. Sober and responsible men of science are not heard by the general public, and are not discussed by "literary critics", while any wild statement is at once commented upon and given the widest publicity — as, for instance, the recent assertion that "in fifty years' time the ratio of the sane to the insane will be as one to one". Students must not rest content with such violent and entirely baseless assertions. In the case of genius, we shall do well to study such volumes as Galton's "Hereditary Genius", Ellis's "Study of British Genius", Larned's "A Study of Greatness in Men" and Myers's "Human Personality and its Survival of Bodily Death", before we are confident that we are at all familiar with what science has to say upon the subject.

The total inadequacy of the theory of genius as degeneration

If we are to require some scientific accuracy of thought and language, we shall begin by describing genius as supernormal, which is an entirely distinct word from "morbid". The two, however, are often confused, in organisms and in conduct. The man who does not act conventionally may be condemned as a sinner, when he is really that very much rarer sort of person called a saint. Of course, he is abnormal, because few people are saints, and the many determine the *norm*, but his conduct is not therefore diseased. Similarly with genius.

Of course it is other than normal, or we should not be discussing it, but that does not entitle us to call it morbid. No doubt this is the easy course. Nordau does not like Wagnerian melody, so he simply calls Wagner a "higher degenerate", and there you are! The greatest Life ever lived was not as the life of others, and so the simple and satisfactory explanation was, "He hath a devil."

Modern pseudo-science, as represented by Lombroso and Nordau, has simply taken up this old cry of the crowd against the genius, "He hath a devil," and has restated it with an array of polysyllables which may convince the ingenuous of its truth.

The want of a standard of sanity in the writers on degeneration

But if we are to be scientific, we shall see very quickly that our task is not an easy one. Before we define a man as insane — that is to say, not sane — it is obvious that we require a definition of sanity; and the remarkable fact is that we have no definition of sanity, and that no one has yet written us a book upon the subject. The literature of insanity would fill a huge library, but not one volume upon sanity, of which insanity is simply the negation, yet exists. The law has a fatuous theory, to the effect that knowledge of the difference between right and wrong constitutes sanity and responsibility; so that, if a criminal is "aware of the nature of his act", he is held responsible. Philosophers would reply that, if knowledge of the nature of right and wrong is required for sanity, nearly all the world is mad; and alienists know that insanity is not a condition of the reason at all, and that hosts of insane people are as well aware of the nature of good and evil as any of the sane.

The first objection, then, to the theory of Lombroso and Nordau is that they have no standard of sanity. In fact, their writings are as scientific as the remark of any of us upon the behavior of any one whom we dislike or do not understand — "the man's mad". Of course, mediocrity cannot understand genius; and, of course, the behavior of genius must be different from ours; its standard of values must be different from ours; and so we can put ourselves in the right by calling genius mad, thus putting it in the wrong.

Dryden's lines not so far from the truth as is pseudo-science after all

The poet's couplet is, in fact, far nearer the truth than the pseudo-science of today. The man of genius is very often "near allied" to the insane person, in the sense that they resemble one another, and agree in differing from ordinary people, in certain respects. But this does not make them identical, except in the eyes of people who are content to judge by superficial appearances, which is precisely what science does not do.

We should remember that psychology is only in its infancy. People talk of meteorology as "the Cinderella of the sciences", but the study of the abysses of atmospheric space is child's play compared with that of the abyss of the human mind. In years to come, men will marvel at the fashion in which we spoke of insanity and genius without any real knowledge of the elements of the problems we were considering. It behooves us to be more humble.

In the first place, the time has surely gone by when we have any right to use such a vague term as genius as if it corresponded to a definite entity in the world of fact. To some extent we cannot help doing so, and may, indeed, do so without harm so long as we keep to certain generalities.

The absurdity of confounding as similar the extremes of psychology

But the outstanding objection to the treatment of genius by the school of Lombroso, as also by the host of literary and other critics who make no claims to scientific authority, is that the same word is used to express the psychological characteristics of men so different as, say, Goethe and Edgar Allan Poe, Newton and Keats, Leonardo da Vinci and Chatterton, Bach, Beethoven, Handel and Schumann.

No one will question that Milton was a poet of genius; no one would have the stupidity to declare that he was insane. No one will question that Lord Kelvin was a man of the highest mathematical genius, and entirely sane; but what possible service can be rendered to science by calling Kelvin a genius and Aubrey Beardsley or Oscar Wilde a genius, and then proceeding to generalize as if we had a scientific definition? Yet this is the general practice; and in the name of science it is necessary to protest that the kind of definition which simply declares that St. Francis of Assisi and Napoleon Bonaparte were examples of genius is of no value at all for science or for logic. There is no better instance in the whole realm of thought of what Bacon rightly condemned as the power of words over the mind and the injury which these "idols of the forum" do to those who cannot detect and avoid them.

The forms of what we call genius are, in fact, as varied as are the forms of mediocrity and talent. Nor is there any absolute difference between mediocrity and genius. Genius merely exhibits, in higher degree, those powers which are displayed, in some degree, by large numbers of ordinary men. We can nearly all invent tunes, some better or worse than others; only Schubert and Wagner and Bach invented the best of all We can all write verse of sorts, we can all conceive poetic ideas; only Shakespeare was more so. We can all perform simple mathematical processes; only Newton and Kelvin could carry more in their heads at a time, and could notice new possibilities where our powers of comprehension and invention stop.

There can be no doubt that, along with the exceptional powers of genius in an infinitude of directions, there may often go certain mental and moral characteristics which seem closely allied to those of insanity. But we should do well to try to understand these everyday phenomena of insanity, as they are displayed by the inmates of lunatic asylums all over the world, before we presume to label genius in this off-hand manner.

The light thrown on insanity by recent searching studies

Thanks to the profound and searching powers of Professor Freud, of Vienna, we are now gradually reaching newer ideas of the psychology of insanity than ever before. These ideas throw much light upon the psychology of ordinary people as well, and they will ere long help us better to understand the psychology of genius. Perhaps the briefest way in which we can define the great contribution of Freud to our knowledge is to say that he begins to direct us to the hidden part of the mind of the insane — or the sane — from which spring, quite reasonably, naturally, inevitably, the modes of behavior which we thought so mad, because we did not perceive the hidden springs of conduct. Once we had the key, the piece of behavior seems quite reasonable, the delusion seems logical and inevitable, from the premises which are in the insane man's mind, but of which we were not aware.

Similarly, if we had the key to the mind of the exceptionally endowed man whom we call a genius, we might see that his behavior, his scorn of the world and its notions, his intense anger over what seems a small cause, and so forth, are the natural and logical consequences of the ideas, the interests, the scale of values which he has in his mind, and which are different from ours just because he is what he is and we are what we are. He may often be inclined to think all the world mad, and from his point of view he may be right, or at least as right as we are in thinking him so. At any rate, we have not begun to understand him unless we grasp the truth that *the key to the conscious is the unconscious.*

The mistake of judging insanity as a simple disease of the brain

Having come so far, we are ready to learn what Myers has to teach us. His great book was published two years after his death, in 1901. In some ways it was before its time, even though the Society for Psychical Research had been founded as much earlier as the year 1882. Orthodox science was then still dominated by the purely mechanical and physiological view of man which prevailed in the latter part of the nineteenth century. Insanity was looked upon as simply a disease of the brain, just as jaundice is a disease of the liver. The essential problems of human personality were ignored. Consciousness was medically and physiologically regarded as a function of the brain, and the existence of the subconscious mind was overlooked in the schools.

Such a thing as the study of human personality was regarded as outside the pale of real science. The brain could be studied, indeed, for it is a material thing, and therefore legitimate material for "positive" or "objective" science. But personality, not being material, and being hard to define and comprehend, was best left on one side altogether. "Hamlet" without the Prince of Denmark was the order of the day in the study of Man.

The world's indebtedness to the psychology of Frederic W. H. Myers

But Myers and the school which he largely helped to found were keeping the flag of psychology flying all the time. They did their best to observe and record certain phenomena, displayed by human beings, with which orthodox physiology would not be troubled, and yet which were undoubtedly facts of Man. If those who read the book which Myers left behind him at the time of its publication would now return to it after reading Bergson, and the contributions to psychology which we owe to Freud, they would be astonished to discover how much we really owe to Myers, with his clear conception of the self, or the part of the self that lies below the threshold of consciousness, and that is therefore often called the subliminal — *i.e.*, under-threshold — part of the personality. All this, which at first sounded like mysticism or fiction to many neurologists, has now entered into their exposition and interpretation of the facts of abnormal mind.

The theory of the activities of genius as advanced by Myers

With no uncertain note does Myers, himself a poet and prose-writer of genius, define *his* view of genius, in the sharpest contrast to that of Lombroso and Nordau. Not only does he assert that true genius is, as genius, if not normal, then not morbid but more than normal, but he also states the theory of the activities of genius which we must try to define as closely as possible, for it is the nearest statement to the truth that has yet been attained. "What type of man," says Myers, "is he to whom the epithet of *normal* — an epithet often obscure and misleading — may be most fitly applied? I claim that that man shall be regarded as normal who has the fullest grasp of faculties which inhere in the whole race. Among these faculties I count subliminal as well as supraliminal powers — the mental processes which take place below the conscious threshold as well as those which take place above it; and I attempt to show that those who reap most advantage from this submerged mentation are men of genius."

The scientific view of genius as defined by Myers

Such is Myers's preliminary statement of his case. He gives his view in more detail.

"Genius — if that vaguely used word is to receive anything like a psychological definition — should rather be regarded as a power of utilizing a wider range than other men can utilize of faculties in some degree innate in all; a power of appropriating the results of subliminal mentation to subserve the supraliminal stream of thought, so that an inspiration of Genius will be in truth a *subliminal uprush*, an emergence into the current of ideas which the man is consciously manipulating of other ideas which he has not consciously

originated, but which have shaped themselves beyond his will, in profounder regions of his being. I shall urge that there is here no real departure from normality; no abnormality, at least, in the sense of degeneration, but rather a fulfilment of the true norm of man, with suggestions, it may be, of something *supernormal* — of something which transcends existing normality as an advanced stage of evolutionary progress transcends an earlier state. . . . The man of genius is for us the best type of the normal man, in so far as he effects a successful coöperation of an unusually large number of elements of his personality, reaching a stage of integration slightly in advance of our own."

For Myers, we see, the man of genius is one who has the most efficient grasp and control of all the parts of his personality. In his own words, "Men of genius, whose perceptions are presumably more vivid and complex than those of average men, are also the men who carry the power of concentration furthest, reaching downwards by some self-suggestion which they no more than we can explain, to treasures of latent faculty in the hidden Self."

Extraordinary evidence of latent mind-power in arithmetical prodigies

Here, of course, we require the scientific evidence for this view of genius, and it is certainly forthcoming. Myers began by citing the case of "calculating boys", arithmetical prodigies, such as those who have astonished the world from time to time. ' These children and youths — it is to be noted that their power usually disappears in later life — can perform, almost instantaneously, the most remarkable arithmetical feats. On inquiry it is found that they do not consciously calculate. The answer " comes into the mind " by " inspiration". Of one of these remarkable persons it was said, " He had an almost miraculous power of seeing, as it were, intuitively, what factors would divide any large number, not a prime. Thus, if he were given the number 17,861, he would instantly remark it was 337×53. . . . He could not, he said, explain how he did this; it seemed a natural instinct to him."

Similar evidence in the higher realms of thought

The case is the same in the higher realms of psychical product. The great mathematician Arago would let a new proposition alone, "and next day I would be astonished at understanding thoroughly that which seemed all dark before". The philosopher Condillac had the same experience. Composers of music and poets have wakened with themes or lines in their heads which could not be reached by their conscious efforts before sleeping. Alfred de Musset said: "One does not work — one listens; it is like an unknown person who speaks in your ear." Lamartine said: "It is not I who think; it is my ideas which think for me". As for Socrates, we all remember how he attributed his ideas to the communications of his "Dæmon".

Similar evidence could be cited to any extent. Ribot, the great French psychologist, sums up the facts as follows: "It is the unconscious which produces what is commonly called inspiration. This condition is a positive fact, accompanied by physical and psychical characteristics peculiar to itself. Above all, it is impersonal and involuntary; it acts like an instinct, when and how it chooses; it may be wooed, but cannot be compelled. Neither reflection nor will can supply its place."

How little true is it that genius is " an infinite capacity for taking pains "

There is a much too celebrated and familiar definition of genius, due to Carlyle, as "an infinite capacity for taking pains". We now see how exactly that definition expresses what genius is not. Sir George Darwin, the mathematical astronomer, perfectly illustrated the high degree of efficiency which can be attained by that infinite capacity for taking pains which he inherited from his father. He mostly used laborious and conscious arithmetical processes of an obvious kind, and he employed them for many hours a day throughout his life, very often finding that days and weeks of labor had been wasted, but sometimes reaching valuable conclusions. He had great mathematical success without a

trace of what can be called genius. Without his infinite capacity for taking pains he would have achieved nothing. Let us consider again the number 17,861. By sitting down to it, by conscious effort and application, we can in time ascertain its factors. But when the number was named to the "lightning calculator", he replied "337 × 53" at once, without any "pains" at all. This is a case of arithmetical genius. Another such would give, in a few seconds, an answer to a multiplication which involved a row of forty figures, and during those few seconds he would talk about the weather, or whatever happened to be the topic of the day. There was no capacity for taking pains there. Taking pains is a conscious process, perhaps the most conscious of processes. The genius, like the mathematical prodigy, like Newton or Kelvin, and unlike George Darwin, "sees" the answer, the new method, the real key to things, "by inspiration". It "comes into his mind", as immortal tunes came into the mind of Schubert on the instant that he read Shakespeare's verses "Who is Sylvia?" or "Hark, hark, the lark!"

The composer of "popular songs" compared with a musical genius like Schubert

But the composer who has no genius, only an "infinite capacity for taking pains", goes to work differently. He reads the verses over carefully, and considers the salient words, "hark", "lark", "heaven's gate", and jots down ideas for the best musical representation of calling attention to the lark's song, and of the celestial gate (probably a tinkling accompaniment high up in the treble). Then he puts these things together, and constructs his song, as an automobile is put together by the assemblage of its parts. The song, or the poem, or the play, or the picture is "machine-made". It may sell, it may even please for a time, but ultimately it is just nothing. There is no genius in it.

No doubt it seems very unfair that industry and application, without genius, should be so hopelessly left behind by the least breath of the authentic thing, but it is so. Many men and women throughout the world live by writing stories, and their great need, of course, is plots. They jot down ideas in notebooks, talk them over with friends, read existing stories, search newspaper paragraphs, etc. Robert Louis Stevenson was endowed with genius, however, which exactly answered to Myers's definition. He would go contentedly to bed at night, and in the morning there was his new tale, all ready — and very hard to beat. He tells us all about it in his chapter on dreams, published in "Across the Plains". He talks of the "little people who manage man's internal theater", and he says: "They have plainly learned, like him, to build the scheme of a considerate story and to arrange emotion in a progressive order; only I think they have more talent. And one thing is beyond doubt — they can tell him a story piece by piece, like a serial, and keep him all the while in ignorance of where they aim." Many of us have wakened with vague recollections of extraordinary incidents, dialogues and the rest, which were presented to us in our sleep, but we cannot retain them. Perhaps they would be Stevensonian if we could. But the contrast between the man of genius and the ordinary worker shows itself in this case of story-writing, just as in the case of a Kelvin and a George Darwin, a Schubert and a composer of the ordinary "popular song".

Wordsworth as an illustration, at different times, of industry and of genius

The great poet Wordsworth admirably illustrates for us, in one individual, both conditions of production. Especially in childhood and youth, as he hints in his greatest poem, he had periods of what we commonly call inspiration, when he seemed "rapt" away from the worldly environment of his body, and came into communication with other things. As he grew older these periods of communication with his subliminal self became rarer, and finally ceased altogether. "The lamp of genius," said Schiller, "burns quicker than the lamp of life." In most of us the fact dies young, and the true significance of childhood in this connection must be referred to ere we conclude. But Wordsworth did not stop writing poetry when inspiration failed.

On the contrary, he displayed an "infinite capacity for taking pains," and throughout his long life of eighty years produced an enormous mass of competent verse, but he wrote practically no real poetry after the year 1808. For the last forty years of his life he was only a skilled and patient manufacturer of verse, with an infinite capacity for taking pains, but no genius.

Those periods during which ideas, images, noble phrases surged up into his conscious or "supraliminal" mind from the subconscious had practically come to an end with advancing years. His genius, "that happy mixture of subliminal with supraliminal faculty", had come to an end. The difference between the two kinds of product stares every reader in the face when he comes to take Wordsworth's poems and read them chronologically.

The student should certainly consult Myers's great pages for himself. But even without his help we can begin to understand how the "Dæmon" of Socrates was really his subliminal self, communicating with the conscious self of that marvelous man of genius.

Joan of Arc an example of the subliminal uprush of genius

Similarly, we realize that the voices and their commands which were heard and obeyed by Joan of Arc were the subliminal self of that girl of genius. The convenient explanation, as usual, was "She hath a devil", and so the English burned her alive. If we wish to obtain further first-hand *data* as to what happens in the course of that "subliminal uprush" which is the inspiration of genius, we should consult Wordsworth's "Prelude", in which the poet has deliberately set himself the task of describing the poetic and inspired state, and which is thus, as Myers has pointed out, of extreme psychological interest as an authoritative document on the subject.

Anatomists and biologists of today tell us that the child is the highest form of the race, and indicates the direction towards which it is progressing, whereas the physical details that distinguish the adult organism are usually degeneracies, and reversions to lower types, like the hairy face of the adult man. We may now begin to see that this is true, in some respects, of the psychical order. Wordsworth, and Vaughan before him, argued that the child "trails clouds of glory", is "nearer heaven", as Hood said of himself as a boy:

> Not in entire forgetfulness,
> And not in utter nakedness,
> But trailing clouds of glory do we come
> From God, who is our home.

"For of such," said the Founder of Christianity, "is the Kingdom of Heaven."

The highest hours of the highest minds men's rarest heritage

The study of genius suggests that the child is the natural, spontaneous genius, and that thus the genius in general is the type towards which man ascends. As Myers has admirably said, "Childhood is genius without capacity; it makes for most of us our best memory of inspiration and our truest outlook upon the real, which is the ideal, world." The men of genius have grown into manhood retaining the privilege of the child, and developing the capacity for making that privilege effective. In them, to quote Myers again:

"We can catch that sense of self-fulfilment in self-absorption, of rapture, of deliverance, which the highest minds have bequeathed to us as the heritage of their highest hours. These our spiritual ancestors are no eccentrics nor degenerates; they have made for us the sanest and most fruitful experiment yet made by man; they have endeavored to exalt the human race in a way in which it can in truth be exalted; they have drawn on forces which exist, and on a Soul which answers; they have dwelt on those things 'by dwelling on which it is', as Plato has it, 'that even God is Divine.' "

Here speaks something higher than knowledge, which is Wisdom. All the knowledge we can obtain supports it. The nature of genius is clearly seen to be as Myers asserts. Cleverness, talent and capacity may construct, combine and manufacture; but genius creates. Cleverness puts things together from without; genius brings into being from within.

Cleverness tries to make an automatic machine by the combination of materials. Life makes its machinery from within, unfolds it from the fertilized egg, in which, indeed, it was not.

Genius the presence in the individual man of the universal creative mind

That is the method of genius. It is creative, and the man of genius is a creator, bringing new things into the world, as Life brings new species into the world. If now we regard Life as essentially psychical; if we look upon the "subliminal self" of every man as the portion of the Universal Mind which displays, or conceals, itself in him, we shall be prepared for the noble and profound definition of genius which we owe to Carlyle, and which is as little known as his irrelevant definition is well known. "Genius," said Carlyle, "is the clearer presence of God Most High in a man." "Dim, potential in all men", in the man of genius it becomes "clear, actual". Hence the mysterious, inimitable character of its doings. In its achievements we see Creative Evolution at work in its highest product, making him higher still.

The essential truth of Carlyle's gospel of hero-worship

If our understanding of genius be sound, we see what a place this great gift takes in the evolution of humanity. Here, again, Carlyle is proving himself to be the sound guide. Bacon thought that his scientific method was to "level men's wits", so that anyone could make discoveries by the honest application of his machinery. The nineteenth century as a whole thought much the same. But genius has been genius in the realms of philosophy and science since Bacon discussed the inductive method of thinking, as before; and the nineteenth century view of salvation by legislation and mechanism and universal education has long since proved to be a delusion.

Only "soul" can save; the "soul of all improvement is the improvement of the soul". The universal tendency to "hero-worship", on which Carlyle wrote so eloquently so many years ago, has a valid use and "survival-value". It is the heroes, the men of genius, that guide and guard and advance mankind, and the best that the rest of us can do is to recognize and value them as we should.

As Carlyle said: "Universal History, the history of what man has accomplished in this world, is at bottom the History of the Great Men who have worked here. They were the leaders of men, these great ones — the modelers, patterns, and in a wide sense creators, of whatsoever the general mass of men contrived to do or to attain; all things that we see standing accomplished in the world are properly the outer material result, the practical realization and embodiment, of Thoughts that dwelt in the Great Men sent into the world; the soul of the whole world's history was the history of these."

"There is but one temple in the universe," says Novalis, "and that is the Body of Man. Nothing is holier than that high form. Bending before men is a reverence done to this Revelation in the Flesh. We touch Heaven when we lay our hand on a human body."

The something in man older and greater than himself

These words ring very true to the modern student of man, and especially of man in his highest forms, who believes that the Mind which is in man, and which made man, is part of the Mind which is behind all things. And the best evidence for this view of man is furnished by the psychological study of the most characteristic facts of the highest types of men, and the mode in which they do what they do by the spontaneous and creative Power of Something which is in them, but is older and greater than they.

PRESENT-DAY WARSHIPS

The Most Terrible Concentration of Power
Achieved by Man Since the Beginning of Time

THE LAST LINE OF OUR NAVAL DEFENSE

THE modern battleship, although perhaps not remarkably beautiful in its general appearance, is the most efficient type of warship that has yet been devised. The hull is of steel, as are most ships of the present day, and is well protected from gun-fire by heavy armor plates so placed that projectiles will not be able to reach the engines, boilers or magazines.

The last battleships designed for the United States Navy, the *Massachusetts* class, were to have a length on the water line of 660 feet, a breadth of 105 feet, and a weight, or "displacement", as it is called, of 43,200 tons. On the main and upper decks, high above the water, twelve guns firing shells sixteen inches in diameter were to be carried in four triple-gun turrets placed on the center-line of the ship. These ships were designed to have a speed of 23 knots, or about 26½ miles, an hour, a speed which is not remarkable in comparison with that of a destroyer, but is considerably higher than that of the first battleships constructed for the Navy. Into the designs of this class of battleships has gone all that modern science, invention and industry can devise, as well as the results of lessons learned from the naval battles of the Great War, and if these ships were completed, they would represent the highest type of offense and defense possible in a warship of the present day.

Under the terms of the naval treaty made in 1922 with Great Britain, Japan, France and Italy, the six battleships of the *Massachusetts* class were not to be finished, but three of the *Maryland* class (the *Maryland*, *Colorado* and *West Virginia*), authorized by Congress in 1916, were to be completed and in fact they have already taken their places among the fighting ships of the United States Navy. They are considerably smaller than the battleships of the *Massachusetts* class would have been, having a length on the water line of 600 feet, a breadth of 97 feet, and a displacement of 32,600 tons, and carrying eight instead of twelve sixteen-inch guns, while the speed is 21 instead of 23 knots. But, on the other hand, they compare favorably with the *Mutsu*, which Japan keeps under the provisions of the treaty, having the same number of sixteen-inch guns. The *Mutsu*, however, making 23 knots, has the advantage in speed.

Although not as powerful as the later designs would have been, the *Maryland* class of battleship is a wonderful concentration of naval power. Their eight sixteen-inch guns have a combined muzzle energy of about 800,000 foot-tons, or enough to lift twenty-five battleships as large as themselves a foot in the air. By means of this energy they are able to throw at every broadside seven and a half tons of steel and explosive at an enemy ship. Each shell weighs 2100 pounds, and eight of these shells can be fired simultaneously, the force of the discharge carrying them at a high elevation a distance of over twenty miles as a maximum range.

The great guns of a battleship have, however, a comparatively short life, for they are soon injured by the force which they create; the rifling of the inner tubes becomes worn away by the powder used in the charges, thus interfering seriously with the accuracy of the gun.

In addition to the battery of large guns, the modern battleship carries a secondary armament of lighter ordnance for use against torpedo craft. A battleship of the *Maryland* class therefore carries fourteen five-inch guns as well as her eight sixteen-inch guns.

The principle on which the battleship is built

The idea underlying warship construction is that of specialization. Each ship is planned only as a part of a battle unit. The maximum destructive force which can be concentrated in a comparatively small space is put into the capital ship, and all that can be saved in the weight of a secondary battery is spent on thicker, heavier armor. Furthermore, the speed of the battleship is kept comparatively moderate so that a saving can be made in the weight of the boilers and machinery, thus affording more armor for protection and more guns for offense.

In some cases the weight of armor is reduced and the additional buoyancy thus obtained is used to increase the power of the engines. In this way the battle cruiser is created, this being the type of warship upon which devolved most of the sea-fighting in the Great War. In almost all respects, except speed and thickness of armor, the battle cruiser resembles the battleship; in fact, it may be considered to be a high-speed battleship, relying upon speed as a means of protection rather than upon heavy armor. Battle cruisers, however, are very effective as scouts and for forming what is known as a "fast wing" for a battle fleet, their duty being to engage the advance ships of the enemy, and then give way to the heavier battleships. For a final fleet action, battle cruisers are not sufficiently protected by armor, as was proved by the loss of the British battle cruisers at the Battle of Jutland.

Great Britain, Germany and Japan have built several battle cruisers, but the United States has never completed any of this particular type of warship. Six were authorized in 1916 but, although partially completed, they were scrapped under the terms of the Naval Treaty. They were to have a length of 850 feet on the water line, and, with clipper bows, of 874 feet over all. Their breadth was to have been 102 feet, and their displacement 43,500 tons. The designed speed was $33\frac{1}{4}$ knots, for which the enormous total of 180,000 horse-power was required. The machinery installation was to be electrical, high-speed turbines being used to drive generators which were to furnish current for the electric motors, which, in turn, were to drive the propellers. Eight sixteen-inch guns were to have been carried in four twin-gun turrets located on the center-line, and in addition, sixteen six-inch guns and eight twenty-one-inch torpedo tubes were to have been carried. The main armor belt was comparatively light, it being considered that the combination of high speed and heavy battery would be sufficient to break through an enemy's advance ships, and, because of their speed, they could accept battle or run away as occasion required.

How the destroyer proved its value in the Great War

Destroyers are a development of the early surface torpedo boats whose function it was to attack larger warships, such as battleships and cruisers, by launching torpedoes against them, and then to trust to their high speed to keep out of harm's way. These torpedo boats never proved very successful in this respect, as they were generally prevented from getting within torpedo range of a large ship by the torpedo-boat destroyers assigned to the fleet in order to protect its battleships and cruisers. These destroyers were provided with guns to be used against the torpedo boats, and also with torpedo tubes which could be used against the larger ships of the enemy if an opportunity occurred to do this. With the coming of the submarine, which on account of its invisibility was easily able to get within torpedo range of a large ship, the surface torpedo boat was of no further value, but the destroyer, because of its extremely high speed and gun power, was able to hunt down the submarine, and so retained

ONE OF UNCLE SAM'S LATEST BIG BATTLESHIPS

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THE UNITED STATES BATTLESHIP *MARYLAND* SEEN FROM AN AIRPLANE

This, one of the latest fighting units of the U. S. Navy, is 600 feet on the waterline, 97 feet beam, with a displacement of 32,600 tons. She carries eight 16-inch guns and has a speed of 21 knots an hour.

its very important duty of protecting the larger vessels of the fleet against torpedo attack. During the Great War, the destroyers proved themselves invaluable in this work, and were most effective in protecting not only the large warships but the merchant ships as well, which carried troops and supplies across the ocean. In hunting down the submarine the destroyers were made extremely efficient by being provided with depth bombs. Upon sighting the periscope of a submarine, the destroyer would immediately start for the spot, and, on arriving there, would drop a series of depth bombs, which in an astonishingly large number of cases were successful in smashing the submarine. Furthermore, on account of its high speed and manœuvering ability, the destroyer could generally keep out of the way of any torpedoes which were launched against it.

The latest destroyers built for the United States Navy have a length over all of about 314 feet, a breadth of 31 feet, and a displacement of 1215 tons. They have a speed of 35 knots, and are armed with four four-inch guns and four triple torpedo tubes which can fire torpedoes twenty-one inches in diameter. Four destroyers are generally assigned to protect a battleship from torpedo attack, and from what has already been said, it is evident that they can be remarkably effective.

Guns *versus* torpedoes

In fighting ships of its own class the battleship relies chiefly upon the power of her guns and on the protection afforded by her armor. The large guns are capable of very accurate shooting even at ranges of five and six miles, whereas the torpedo at this range is practically useless. Even supposing that an enemy's ship does come within torpedo range, the chances of a hit are rather doubtful for the reason that between the time a torpedo is discharged and the time when the torpedo has covered a mile or two, the ship aimed at will probably be over a mile from its original position. Even though the torpedo is aimed at the spot which the ship is supposed to reach, a hit is very problematical.

But a shell from a big gun, with a muzzle velocity of 2700 feet per second, will travel five or six miles in less than that number of seconds, and the ship aimed at will have had time to travel barely half her length. Thus the big gun excels in both quickness and sureness of aim, and although the destructive force of a single bursting shell is somewhat less than that of a torpedo, the rapidity and accuracy of fire obtainable with the big gun makes it the most efficient weapon for the battleship.

At the present time, the battleship of the dreadnought type is supreme in fighting ability. All that the ablest minds in industry and science can devise with the aid of the resources of modern civilization to produce the utmost energy of destruction, is combined in these leviathans. Furthermore, the lessons learned from the Great War still indicate that this type of warship will probably remain for some years to come the most effective naval fighting unit that can be had.

Turrets

On the four turrets which contain the eight sixteen-inch guns of battleships of the *Maryland* class an extraordinary amount of inventive genius has been spent. These turrets are placed along the center-line of the battleship — that is to say, along the keel-line running from bow to stern. In some of the earlier dreadnought battleships, the turrets were not all so placed, but now that this arrangement has proved so advantageous, it may appear difficult to understand why the center-line system was not adopted in the first *Dreadnought* built by Great Britain back in 1905. The fact was that all the great naval powers — except the United States — were ready to sacrifice from twenty to forty per cent of the broadside fire of their battleships in order to retain a powerful bow and stern fire. If the turrets are all placed on the same level down the center-line, there will be only two or three guns available for firing at an enemy directly in front or directly behind, but the United States surmounted the difficulty of combining a full broadside of eight, ten, or

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U. S. BATTLESHIP *CALIFORNIA*, FLAGSHIP OF THE PACIFIC FLEET

© Underwood & Underwood, N. Y.

THE PRIDE OF THE JAPANESE NAVY, THE DREADNOUGHT *MUTSU*

twelve guns with an end-on fire of four, five, or six guns, by building the second turret higher than the first, and the third turret higher than the fourth. The guns in the two higher turrets are fired over the tops of the two lower turrets in an end-on action. This arrangement of turrets was first used in the *Michigan* and *South Carolina* authorized in 1905.

For some years no other nation followed the lead of the United States, there being a general feeling that the Americans were taking too many risks for the sake of a theoretical advantage. What will occur, said foreign naval designers, when the blast from the upper guns sweeps over the lower turret, and what will happen to the men and machinery in the lower turrets? It has been shown, however, by experiment, and also by actual experience in the Great War, that when the guns in the upper turrets are fired directly over the lower turrets the men in these lower turrets are not inconvenienced in working their own guns. Furthermore, although the forces acting on the structure of the ship when all the big guns are fired on the broadside are tremendous, the ship easily withstands them and simply heels a little under the force of the blow. The design of the turrets, as well as that of the mounts for the guns is therefore very complicated, and requires the highest type of engineering skill and inventiveness.

Big guns

It is not a difficult matter nowadays for a great industrial nation to construct big guns. For some years the United States Navy has used fourteen-inch guns; many of the British battleships carry fifteen-inch guns; and, as already stated, the latest ships of the United States and the Japanese navies have sixteen-inch guns. During the Great War Great Britain tried eighteen-inch guns. One of these was mounted on the fast cruiser *Furious*, and, according to unofficial accounts, its firing shook the vessel considerably. Another was mounted on the monitor *Lord Clive* and was used in the bombardment of land fortifications.

Although the manufacture of large guns is not particularly difficult, the construction of a mounting which will enable the ship to stand the shock of a broadside of them is a very different matter. It is not as though the gun were placed on a firm foundation; it is put into a turret which turns around on rollers; it must be carefully balanced; and practically all of the smashing force of the recoil when it is fired must be taken care of by mechanism placed within the turret. So the latter, on a battleship, besides the two or even three big guns, contains a wonderful mass of machinery: the gun-elevating mechanism, the turret-turning gear, the shell and powder hoists. There must, as well, be space for handling the powder and shell.

Operation of the big guns

Practically everything is done by machinery on board a modern battleship, steam, compressed air, hydraulic power, and electricity being used to operate the various kinds of machinery. Take, for instance, the loading of the big guns. The actual physical labor of the gunners in the turrets and handling rooms is comparatively light. The shells are stored in the magazines in the hold of the ship, and from there are carried by traveling hoists to the main shell hoists running up into the turrets. All that the gunners have to do is to open the breech of the gun, and the shell, weighing nearly a ton, is forced by the ramming mechanism into the bore of the gun. The gunners then close the breech and the gun is ready to be fired.

Still more wonderful is the way in which the guns are fired. High above the decks of the ship are the observation stations, supported by the so-called "cage-" or "basket-" masts. From these points of vantage, the position of an enemy's ship can be studied with the telescopic range-finding instruments, and by means of voice tubes and telephones, the information can be communicated below to a central station. In this room, which is well down in the ship for the sake of protection, the observations received from above on the enemy's speed and range are carefully studied and plotted out on charts so that

BOTH TURRETS FIRING A BROADSIDE

AT THE MOMENT OF FIRING

Courtesy Sir W. G. Armstrong, Witworth & Co., Ltd.

A MOMENT LATER

The Brazilian battleship *Minas Geraes* firing her battery of ten 12-inch guns.

the change in the position of the enemy may be estimated from time to time, and the necessary elevation and train for the big guns worked out. By this means the guns can be kept pointed constantly at the target, and when the signal to fire is given, all the guns or a part of them can be fired from a single station.

From the spotting platform high above the decks the fall of the shells can be watched, and if at first they fall too short or too far, by estimating the distance from their splash to the enemy's ship, the exact range can soon be found.

Conning tower

Overlooking the bows of a battleship is a small, heavily armored tower; in the thick steel that forms its sides there are slits too narrow for a shell to enter, but wide enough to enable a man to see for miles across the sea in front and on either side. This is the conning tower. In it, during an action, stands the captain of the ship and the officers who assist him in controlling its movements. For this purpose the conning tower is provided with compasses, steering wheels, and the necessary telegraphs, telephones, and voice tubes leading to all parts of the ship. The sole aim of the captain is to manœuver into such a position as to give the fire control officers the best opportunity for using the great guns.

Boilers

In the battleship *Maryland* there are eight boilers for providing the necessary steam power and a great variety of mechanisms for converting this power into locomotion, electricity, compressed air, and hydraulic force. In the center of the ship, well protected by heavy armor, are the main turbines, electric generators, and motors of nearly 30,000 total horse-power, which drive her at a speed of over twenty-four miles an hour. Over two thousand tons of fuel oil are carried by the ship to be burned in the furnaces, and the hot gases of combustion are circulated round and round the boiler tubes so as to get as much energy as possible out of the fuel.

The boilers, most of which in the United States battleships have been made by the Babcock & Wilcox Company, are composed of banks of small tubing. They are of the type known as "water-tube" since the tubes are kept full of water, while the hot gases from the furnace pass around them. In the Scotch, or "fire-tube" boiler, the gases pass through the tubes which are surrounded by water. The water-tube boiler has several advantages over the fire-tube boiler for warship work, as it can make steam much faster, is lighter and smaller for the same power, is easier to repair, and is less liable to disastrous explosion if pierced by shell fragments.

Ship control

So much trouble has been taken by all the great navies to give their battleships a powerful end-on fire that any man not an expert would think that a bow or stern fire of four or six guns is of supreme importance. It might be supposed that when a ship only shows to the enemy its narrow bow, which increases aft at the most to a breadth of barely thirty yards, it would present a very small mark. It might also be supposed that when a ship turns to fire her broadside at the enemy, and presents in turn a length of about two hundred yards, it would be a much easier target.

This, however, is all quite wrong. It is hardest to hit a ship that lies broadside-on, and easiest to hit her when only her bow or stern shows. Let us explain the matter from the point of view of the fire-control officer. His great difficulty is to get the exact range of the enemy. The big modern gun, fitted with special machinery, and having an immense muzzle energy which keeps the shell true to its mark over a long distance, can be aimed straight by any well-trained gunner. The problem is to set the gun at the exact elevation necessary to make the shell fall at, say, 9000 yards. An almost microscopic difference in the tilt of the gun will cause the shot to fall, say, 9050 or 8950 yards. The shot may be quite straight, and yet go over the enemy's ship or splash harmlessly in front of it, if the ship is steaming

broadside-on. For then she presents only her breadth of thirty yards. If, on the other hand, she is steaming end-on (let us say she has given up the fight, and is running away with only her stern showing), then the shot fired at her will tell no matter whether it is fifty yards short or fifty yards over. Elevated to a range of 9050 yards, the shell may plow through the funnels or mast and strike a turret near the bow; while at a range of 8950 yards it may strike one of the stern turrets and disable it.

Practically everything in vessels of the battleship type has been subordinated to the needs of fire control and ship control. The only means of adding to the terrible power of a battleship is to increase the energy and smashing force of the big guns, and for this reason naval designers have for many years devoted themselves to the task of working out the center-line system of turrets and superfiring turrets and mounting a bigger gun. The old twelve-inch has given way to the fourteen, fifteen, and sixteen-inch gun,

U. S. Navy Official Photograph

SEAPLANE BEING LAUNCHED BY TURNTABLE CATAPULT FROM DECK OF U. S. S. *MARYLAND*

Thus the captain in the conning tower will manœuver to get his ship within about five or six miles of the enemy and broadside-on. His ship will then present a smaller target, and the fire-control officer will probably by that time have secured the exact range and can fire his guns at the enemy every two minutes or so.

A battle between two modern warships, or between two fleets, is therefore a form of duel in which ship control plays a most important part, each side endeavoring to the best of its ability to secure the most favorable position.

and even eighteen-inch ordnance has already been tried. It is doubtful, however, if the latter is used for some years to come, as under the terms of the Naval Treaty of 1922 the size of guns to be carried on capital ships is limited to those of sixteen-inch caliber. As regards ship control, the speed of battleships has been gradually increased, the engines have been greatly perfected, in fact, everything possible has been done to better the manœuvering ability of the ship, so that she may be able to secure a favorable position on the firing line.

THE VERY LATEST TYPES OF UNCLE SAM'S

BATTLESHIP: U. S. S. *WEST VIRGINIA*

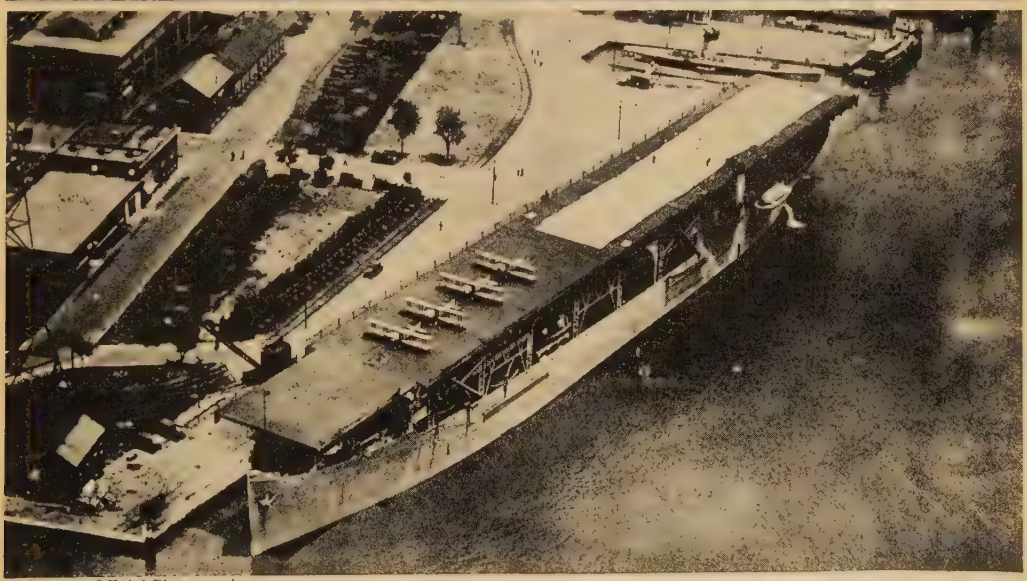
CRUISER: U. S. S. *SEATTLE*

U. S. Navy Official Photographs

LIGHT CRUISER: U. S. S. *RICHMOND*

© N. Y. Shipbuilding Corporation

DESTROYER: U. S. S. *BROOKS*



U. S. Navy Official Photographs

AIRCRAFT CARRIER: U. S. S. *LANGLEY*

The broadside view shows seaplane leaving the deck, the airplane view shows four flying machines parked on the deck.

Armor

The principal problem connected with the gun relates to its power over armor plate. It is still somewhat of a question whether or not the big gun has conquered armor. For many years the battle between them has raged; and for a long time armor was victorious. The battleship carries thick armor around all her vital parts. She has also armored decks. Furthermore, she is minutely subdivided into a great many small compartments so that if her sides or bottom are pierced either by shells or by torpedo or mine explosions, the extent of the damage is so localized that there is but little danger of her sinking.

Modern armor was invented by Krupp in 1893, and has since been considerably improved by the various makers, most of the processes for this being kept practically secret. Usually it is formed of steel mixed with small quantities of nickel, chromium, carbon, and one or two other things. It is cast, heated, and forged, like the gun, under a hydraulic press. Then it is reheated and planed and cemented. It is put into a cementation furnace, where its face remains in contact for some weeks with specially prepared carbon. After this it is plunged into an oil bath, reheated, cooled, heated again, and bent in a bending press, and again heated and chilled. Then it is machined and drilled, and again heated. Thus is formed the hardest and most resistant substance that human skill can devise.

Hard armor of this sort cannot be easily perforated even by projectiles from the largest guns. Shells filled with high explosives are useless against it in the ordinary way. If a common shell explodes on touching the plate, it does very little damage. Shells are made of forged, hardened, and tempered steel, but the very hardest of them is generally shattered against a thick armor plate of modern manufacture. In 1894, however, Russia made some startling experiments with a new kind of shell that shot through armor plates. A cap of wrought iron or soft steel was placed over the hard point of the shell. When the capped projectile was fired against armor, it had an extraordinary effect. For the soft cap supported the hard point, and prevented it from being crushed, and so the projectile was able to perforate the hard-faced layers of steel.

This invention of an armor-piercing projectile was first thought to have decided finally the battle between the big gun and the armor plate. In the Russo-Japanese War, however, no thick belt or turret armor was perforated; and even during the Great War the cases in which thick armor was perforated by projectiles were comparatively few. Breaking through a straight, vertical piece of plate, erected as a target, is an interesting test of the power of a gun and its capped shell. On a battleship, however, most of the armor is curved and the ship is in motion, and the projectile must strike nearly normally on the plate in order to force its way through. Thus the chance of perforation is really quite small; and, in spite of general opinion to the contrary, armor has remained up till now in advance of artillery, especially at the ranges at which modern naval battles are fought.

As things now stand, the lessons learned from the naval battles of that war show that the modern battleship is still the best weapon of defense that it is possible for a nation to have. Without Great Britain's Grand Fleet of battleships to keep the seas clear of German warships, to help the United States in sending her troops to the aid of the Allies, and to prevent Germany from obtaining supplies from outside her borders, the German High Seas Fleet would have easily controlled the sea, and Germany would have soon won the war. So that while the cost of constructing battleships, cruisers, destroyers, submarines, guns, torpedoes, and the numerous other items required in a well-balanced navy may seem very burdensome in time of peace, it should be remembered that preparedness is the best of investments and that the day may come when the Navy will be called upon to save the nation from defeat and slavery, as well as prevent the destruction of countless lives and untold property.

TALKING FROM SHORE TO SHIP AT SEA

© E. Mullen, Jr., N. Y.

U. S. BATTLESHIP *NEW HAMPSHIRE* WHOSE ANTENNÆ CAUGHT THE MESSAGE AND SENT BACK A REPLY

THE SECRETARY OF THE NAVY AT THE NAVY DEPARTMENT IN WASHINGTON TALKING BY WIRELESS TO THE CAPTAIN ON BOARD THE *NEW HAMPSHIRE* AT HAMPTON ROADS

Modern naval battles

When John Paul Jones sailed the seas and made our early naval history a thrilling story, actions were fought at point-blank range and often ships were lashed together while the crews engaged in a hand-to-hand struggle for supremacy. Today there may be ten miles between the two opposing fleets which pour a perfect hail of projectiles at each other.

The science of warship construction advances so rapidly that with every great war new weapons are used which were not in existence when the last naval battles were fought. The submarine was in its infancy during the Russo-Japanese conflict and no one had ever heard of a battle cruiser. Nevertheless, on these two types of ships devolved most of the fighting of the war, with the destroyer playing an important part. Mines filled with high explosive were invented by an American about the time of the Revolutionary War and used to some extent and with success in the Civil and Russo-Japanese wars. They were used in the Great War on such an enormous scale as to make all former attempts seem insignificant. The North Sea mine barrage was 230 miles long, 25 miles wide, and contained over 70,000 mines. At Jutland a mine layer was dispatched for the first time to lay mines in the path of a retreating fleet.

During a modern action the electric leads may be cut and the ship plunged into darkness. Storage batteries for local circuits may then be used. Some ships resorted to candles at the Battle of Jutland. All the signal halyards may be cut and the wireless destroyed so that an admiral has no means of signaling to his fleet. He must then be transferred to some more fortunate ship. Although poison gas has not yet been used in a naval battle, masks were provided by both British and Germans, and men were sick from the stench of exploding shells. The necessity of better protection for magazines was clearly shown at the Battle of Jutland, where three cruisers were blown up, and all naval construction has been influenced by this lesson.

Only by a study of the naval battles of the Great War can we hope to imagine what will happen if the nations go to war on the sea again. In any event, it is well to remember that in all history no war has been lost by a nation which had the command of the sea.

Coronel

The first naval battle

The first naval action of the Great War in which a number of ships took part was fought in the Pacific off the Chilean coast. On November 1st, the British armored cruisers, *Good Hope, Monmouth* and *Glasgow* came up with a German squadron of two armored cruisers, the *Scharnhorst* and *Gneisenau*, and two light cruisers, the *Dresden* and *Leipzig*.

The wind was very strong and the sea was running so high that it was only possible to use the guns on the upper decks out of reach of the spray. The German squadron, being superior, declined action until the sun had set and the British ships were silhouetted against the western sky. Range finding for the Germans was thus easy, whereas it was extremely difficult for the English to see the German ships.

The action lasted for an hour, starting at a range of 12,000 yards (6½ miles). The *Good Hope* was lost by an explosion following a fire. Captain Luce of the *Glasgow* described the scene at 7.50 P.M.: "An immense explosion occurred in the *Good Hope* amidships, flames reaching 200 feet high. Total destruction must have followed."

The *Monmouth* was soon after destroyed by gun fire but the *Glasgow* was able to escape at full speed.

Falkland Islands

On December 7, 1914, the battle cruisers *Invincible* and *Inflexible* arrived from England to join the fleet of old armored cruisers at the Falkland Islands and to attempt the destruction of von Spee's ships which had sunk a number of British cruisers off Coronel in November and were threatening English commerce.

Coaling was immediately begun, that the ships might be ready for sea if the enemy should appear. At 8 A.M. on the following morning, which was clear with a calm sea, two men-of-war were seen steering north. Coaling was only partially completed, but the colliers cast off with all the precision of naval discipline and all ships began to get up steam as quickly as possible. Three quarters of an hour later when the *Kent*, acting as guard ship, was at the entrance of the harbor, the first two ships were about eight miles off and others were sighted some twenty miles away. The cruiser *Canopus* exchanged shots with the two German cruisers, firing at them across a bar of land which inclosed the harbor. They hoisted their colors and turned away to join the three 3rd class cruisers further out to sea. By 9.45, the British squadron put to sea and took up the pursuit. As the old saying is "a stern chase is a long one", so it was 1 o'clock before the first shots were fired from the *Inflexible* at a range of 16,500 yards (9½ land miles). The German 3rd class cruisers turned away and were chased by the British armored cruisers while the two battle cruisers continued to overhaul the two German armored cruisers *Scharnhorst* and *Gneisenau*. Both squadrons manœuvered for position and the range varied between 13,000 and 16,500 yards. The firing was intermittent, but the *Scharnhorst* was badly on fire by 3.30. Shortly after 4 o'clock she suddenly listed heavily and sank in fifteen minutes. As she lay for a few minutes rolled over in the water, many of the crew could be seen clambering down her side, some even jumping from the bilge keels into the water. Only a few could be rescued. The *Gneisenau* put up a plucky fight against the two British warships. Against such overwhelming odds, she was in serious condition by 5.30 with steam escaping and fires everywhere. However, she kept on firing with the one remaining gun. She heeled over at 6 o'clock and sank.

Meanwhile the British armored cruisers had despatched two of the three German 3rd class cruisers, the *Dresden* being the only one to escape.

Dogger Bank

Modern naval battles are fought under conditions to which history offers no parallel. Only a few officers and men in the conning tower, at the range finders and in the masts are able to see what is going on. By far the majority of the men are working behind the armor passing shells, or in the engine and boiler rooms below the protective deck. These men see and know nothing of how the battle is progressing, but on their efforts depend the success of the fleet.

Early on the morning of January 24, 1915, a British squadron encountered a German force off the Dogger Bank. Vice Admiral Sir David Beatty on the flagship *Lion* commanded five battle cruisers, supported by seven light cruisers and destroyers. Vice Admiral von Hipper commanded three battle cruisers and the armored cruiser *Blücher*, supported by six light cruisers and a destroyer flotilla.

The action commenced with the light forces at 7.25 A.M. Admiral Beatty directed the action from the bridge, since he could get a clearer view of what was going on there than through the slits in the armor of the conning tower. Von Hipper is reported to have done the same thing. Beatty ordered full speed in order to overtake the Germans, who were only able to make 25 knots on account of the *Blücher*. This is an excellent illustration of the old adage: "The speed of the fleet is the speed of the slowest ship." The British were able to work up to 28½ knots, which greatly exceeded the designed speed of two of their ships. Admiral Beatty cited the engineering staffs of the *New Zealand* and *Indomitable* in his despatches for this accomplishment.

The flagship *Lion* led the British line of battle and the *Blücher*, being the slowest ship, brought up in the rear of the German fleet. The *Lion* fired an occasional shot at the *Blücher* to test the range and at 9 o'clock scored a hit. The range was 18,000 yards (over 10 miles), a distance so great that the enemy could only be seen by the fire-control officers in the masts. The *Lion* now began to

fire at the ship ahead of the *Blücher* while the latter was being shelled by the two ships following the *Lion*. In order to ease the pressure upon these ships the Germans threatened a torpedo attack with destroyers which was repulsed. This was the first time that destroyers were ever employed to make a massed torpedo attack on a squadron of capital ships.

At 9.45 the *Blücher* showed signs of the tremendous gun fire she had been subjected to. The *Lion* was now firing at the leading German ship, the ships following her attacking the corresponding German vessels. Both fleets were racing across the North Sea at terrific speed, some of them emitting immense clouds of smoke from fires on board, set by exploding shells. Occasionally, a projectile falling close to a ship would throw tons of water over her from the splash of its plunge into the sea. This helped to extinguish many of the fires.

The Germans laid down a smoke screen with destroyers to hide the movements of their squadron and to escape the British by changing their course. The *Blücher*, severely damaged, with her engines wrecked, leaking badly and with the coal bunkers on fire, was unable to stay in the battle line. Some of her guns were still in action and continued firing with great courage. Beatty despatched the *Indomitable* to complete her destruction, and she was later sunk with a great explosion, probably due to a torpedo.

Meanwhile the British ships had not remained unscathed. The *Lion*, being the leading ship, naturally received the worst punishment. A shell struck one of the feed tanks at 11 o'clock so that the port engine could no longer be operated. Beatty transferred his flag to the *Princess Royal* by a destroyer — a feat requiring superb seamanship. Meanwhile a Zeppelin and a seaplane unsuccessfully attempted to drop bombs on the destroyers which were rescuing the survivors from the *Blücher*.

Before Beatty was able to board the *Princess Royal* the pursuit was broken off, though his last order was to close in and attack the enemy. The presence of submarines and the danger of mines has been ascribed as the reason for allowing the Germans to escape, although certainly two of the battle cruisers were in a dangerous condition. The *Lion* had to be towed back to the naval base at Rosyth, where she arrived with a 15 degree list.

The superior speed and larger guns of the British ships proved a powerful advantage to them, as well as their superiority of numbers. Considering the very important part which the battle cruisers played in the war, particularly at Dogger Bank and Jutland, it is difficult to imagine successful tactics for the United States Navy if opposed to a first-class naval power, since we possess no battle cruisers.

Jutland

On the afternoon of May 31, 1916, the greatest naval action of the war was fought off the coast of Jutland. The British Grand Fleet was making one of its occasional sweeps through the North Sea, headed by the Rosyth battle cruiser squadron of five ships, four dreadnoughts of the *Queen Elizabeth* class, three light cruiser squadrons and four destroyer flotillas. A distance of forty-four miles intervened between the battle cruisers commanded by Vice Admiral Beatty and the Grand Fleet of twenty-four dreadnoughts under Admiral Jellicoe.

Shortly after two o'clock the squadrons had just turned north toward their bases when the light cruiser *Galatea*, which was late in turning, sighted an enemy destroyer to the south. Pursuit was immediately begun, resulting in the appearance of German light cruisers and more destroyers. Beatty sent up an airplane to reconnoiter. Weather conditions were such that the airplane had to fly low, but the information was obtained and the pilot returned successfully, although his machine was damaged by enemy fire. It is probable that the Germans intended to use a Zeppelin to scout ahead of their fleet but the low-lying clouds made this impossible.

The German force consisted of five battle cruisers with destroyers and a number of light cruisers commanded by Ad-

miral von Hipper. Beatty worked the battle cruisers up to full speed, the four dreadnoughts, being slower, falling about five miles astern. At 3.48 the fighting began at a range of 18,000 yards, or about ten land miles. In the next hour was fought one of the hottest phases of the battle. The two lines were racing south toward Admiral von Scheer's High Seas Fleet of twenty-two battleships some fifty-six miles off, whose presence the British did not know, and the British Grand Fleet was following astern unsuspected by the Germans.

The shooting on both sides was remarkably fast and accurate at the beginning of the battle. Fifteen minutes after the action commenced the British battle cruiser *Indefatigable* blew up. Twenty minutes later the *Queen Mary* suffered the same fate. Although the ships were steaming only 500 yards apart at a speed of 25 knots (nearly 29 miles an hour), when the *Tiger*, which was the next ship in the line, passed the spot where the *Queen Mary* was hit, her stern was sticking way up in the air with her propellers still revolving. As the *New Zealand*, the ship following the *Tiger*, passed, the *Queen Mary* rolled over and sank completely out of sight. An officer in the conning tower of the *Tiger* describes the scene as follows:

" . . . As they hit I saw a dull red glow amidships and then the ship seemed to open out like a puff ball, or more like one of these toadstool things when someone squeezes it. Then there was another dull red glow somewhere forward and the whole ship seemed to collapse inwards. The funnels and masts fell into the middle and the hull was blown outwards. The roofs of the turrets were blown 100 feet into the air. Then everything was smoke and a bit of the stern was the only part of the ship left above water. The *Tiger* put her helm hard-a-starboard and we just cleared the remains of the *Queen Mary's* stern by a few feet."

A gunner's mate who was one of the few survivors of the *Queen Mary* believed

U. S. Navy Official Photograph

U. S. DESTROYERS LAYING DOWN A SMOKE SCREEN

the explosion was caused by a shell penetrating to the working chamber of "B" turret, igniting the shells stowed in the ready-service rack, and the flames from this conflagration passing to the magazine. This idea is supported by the experience of the *Lion*. About ten minutes after the action commenced the cordite powder in her "Q" turret was ignited by a shell coming through the roof of the turret. The turret officer, though severely wounded, appreciated the seriousness of the situation and ordered the magazine to be flooded. The water-tight doors were quickly closed, a valve was opened in the bottom of the ship, and the sea rushed into the magazine, filling all the space around the powder. Three men out of the seventy of the turret and shell-handling crew escaped alive. In spite of the fact that only the powder being passed from the magazine through the handling rooms to the guns was ignited, flames shot out through the top of the turret as high as the mast.

In the meantime, the four ships of the *Queen Elizabeth* class came up to within 20,000 yards of the Germans and opened fire at this extremely long range. As in the Dogger Bank action, attacks and counter attacks were executed by the destroyer flotillas on both sides with little material success. Torpedo attacks are carried out at top speed (36 knots) in order to make it more difficult for the enemy to hit at the close ranges to which the destroyers approach. Two British destroyers which came under the direct fire of the German ships made good a most spectacular escape. Throwing out as much smoke as possible to screen themselves, and watching for the flash from the enemy's guns, they zigzagged so fast that although the place where they had been a moment before was whipped with shells, they were unscathed.

At 4.38 the British 2nd light cruiser squadron reported the High Seas Fleet in sight and Beatty altered his course from south to north followed by a similar move on the part of von Hipper. The Grand Fleet was at this time some forty miles to the north and coming up at full speed. The 5th battle squadron, *i.e.* the four *Queen Elizabeths*, turned behind the battle cruisers, but just at the turn the *Warspite's* helm jammed so that she ran helplessly in several circles. Von Scheer with the High Seas Fleet was now within range (6.20 P.M.), and the *Warspite* was subjected to a terrific hammering which no one would have supposed she could survive. The executive officer, in a letter describing the action, writes:

"The whole leading enemy division concentrated on us during this circling and we got very heavily hit, and everybody thought we had gone. The Germans thought so too, and ceased firing, luckily for us, but they no doubt could not see us for splashes, spray, and smoke. Terrific rumbling of heavy firing and the whole horizon lit by orange flashes everywhere: everything blurred and beastly." The ship was finally extricated by steering with her propellers and the timely appearance of the vanguard of the Grand Fleet prevented the Germans from further harassing her.

About 6.30 Beatty was reinforced by Rear Admiral Hood with three battle cruisers and he proceeded to turn east across the front of the German line in order to cut off their retreat and give Admiral Jellicoe a chance to bring the Grand Fleet into action. The manœuver was executed with great daring and placed the Germans in a most precarious position, but Hood's flagship, the *Invincible*, was blown up, probably in a similar way to the *Queen Mary* and the *Indefatigable*. Only six of the 1025 officers and men survived. At 7 o'clock, Beatty altered course to the south and southwest, regained contact with the enemy at a range of 15,000 yards, so that the Germans were caught in a semicircle with the Grand Fleet at the north going south and Beatty's battle cruisers working around to the southwest. The action was intermittent, as the light was failing and fog banks were coming up.

The German destroyers laid down a smoke screen behind which von Scheer was able to retreat to the westward. At 6.55 he turned east again, deciding "to advance regardless of cost and bring all

the destroyers to the attack". At 7.17 he thought better of this and turned west again, breaking off the action under cover of a destroyer attack.

Finding himself in a very serious position, von Scheer launched two torpedo attacks at the Grand Fleet with destroyers; one at 7.10 and one at 7.25 with orders "to fight to the death" in the hope of making the English turn away, thus allowing him an opportunity to escape. Only the dreadnought *Marlborough* was hit, and she was able to remain in action. Nevertheless, they caused much anxiety on board the British ships and Jellicoe altered his course to evade the torpedoes. The *Agincourt* barely escaped by making a quick turn of 90 degrees, a torpedo passing close on each side of her.

With the Grand Fleet deployed, *i.e.* one ship following in the wake of another, behind the battle cruisers, the length of the entire British fleet was between twelve and fifteen miles. The noise was more terrific than the roll of continuous thunder and the whole horizon seemed filled with flashes of flame from the guns.

Between 7 and 8.30 o'clock, Beatty regained touch with the Germans, engaging two battleships and two battle cruisers at approximately 10,000 yards. Three of the German ships were set on fire.

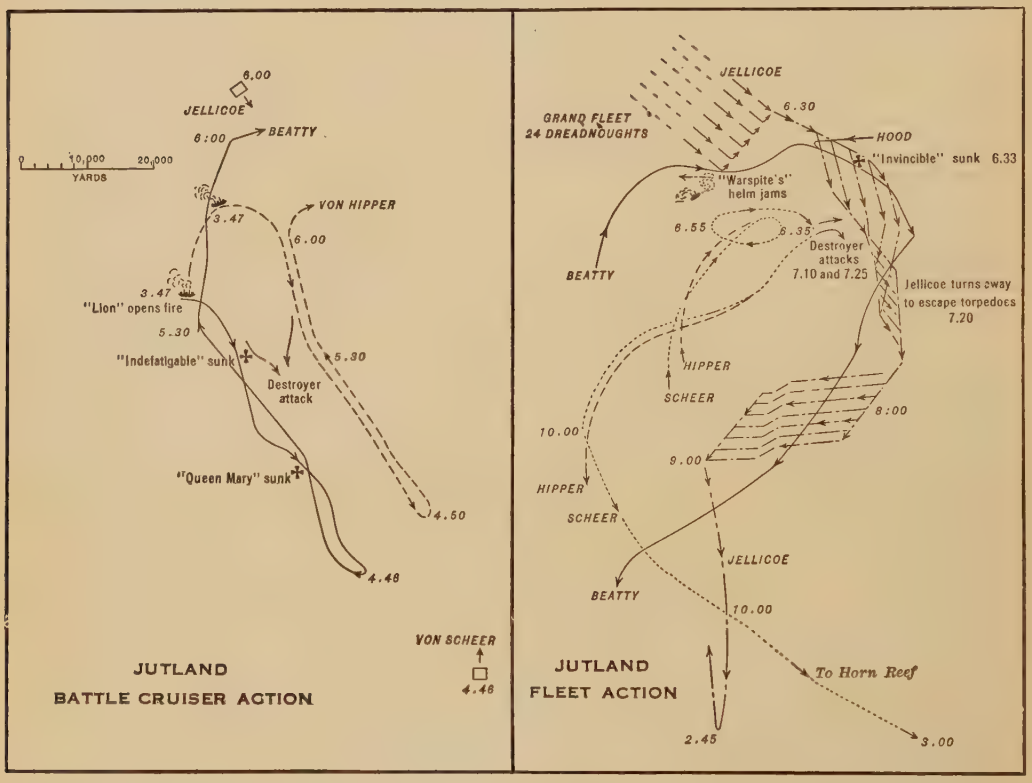
U. S. Navy Official Photograph

U. S. SUBMARINE TENDER *BEAVER* AND SUBMARINES AT GUAM

Von Scheer's fleet had been severely damaged, particularly the battle cruisers on which devolved the brunt of the fighting. Thanks to the fact that the Germans had a better system of protection, no magazines exploded, even though the British had the big advantage of 13.2- and 15-inch guns over the 11- and 12-inch German guns. The battle cruiser *Seydlitz* was so badly damaged she had to be

beached in order to prevent her sinking, the *Derfflinger* had only two 30.5-cm. guns and two 15-cm. guns still firing and over 3000 tons of water had come aboard through shell holes. All her signal apparatus was destroyed except the wireless receiving apparatus, and three of her four turrets were so filled with poisonous gas from the shells as to be untenable. Although there is no evidence to show that poison gas was employed by either side, both British and Germans were equipped with gas masks and there was difficulty in the morning. Anticipating the possibility of von Scheer selecting such a course for his return, Jellicoe ordered a mine layer to lay mines off Horn Reefs lightship. The battleship *Ostfriesland* was damaged by striking one of these mines.

During the night, there were a number of minor but hot and spirited actions, principally between destroyers or light cruisers. The British destroyer *Spitfire* rammed a German cruiser, coming away with some 60 feet of her side plating. Star shells were sent up and searchlights played here and



in both fleets from the noxious gases given off by the explosive in the projectiles. Von Hipper's flagship the *Lutzlow* was so damaged that he transferred to the *Moltke*. The *Lutzlow* was abandoned the next morning by the Germans and sank.

By nine o'clock contact between the two fleets had been completely lost. The Germans were in flight for the protection of their mine fields and a clear passage through these to their bases by way of Horn Reefs. Jellicoe endeavored to collect his fleet for a renewal of the struggle there over the melée of hostile ships. It was almost impossible to tell friend from foe in the confusion. In the dark of midnight, the German fleet slipped past behind the British, who had been between them and their base, and at dawn saw the safety of Horn Reefs with no enemy warships on the horizon.

At 2.45 Jellicoe had turned north again, and his position was discovered by a Zeppelin about 4 A.M., thus assuring von Scheer that the English commander-in-chief could not renew the battle.

At noon on June 1st Jellicoe shaped his course for Scapa Flow. On the night of June 2d the battle fleet was refueled and reported ready for sea again. It was not until June 3d that the last damaged British ship was back in harbor, two damaged battleships and six damaged destroyers having proceeded home independently after the battle.

Mr. Arthur Pollen calculates that in battle practice, carried out against a towed target and therefore against an object much slower and more sluggishly manœuvered than a dreadnought in action, an average of one hit per gun every four minutes at a range of 14,000 yards is not uncommon. At Jutland the opposing fleets made one hit per gun every three or four hours.

Captain Persius in the *Berliner Tageblatt*, commenting on the battle, said: "Had the weather been clear or von Scheer's leadership less able, the destruction of the whole German fleet would have resulted. The long-range British guns would have completely destroyed the lighter-armed German ships." Although the action was of the most gigantic proportions the world has ever seen, it was really only the beginning of a decisive action never fought between the two battle fleets, owing to the weather and falling darkness. Had daylight lasted a few hours more, it is difficult to imagine other than a fatal defeat for von Scheer. Since during more than two years of war after the Battle of Jutland the German fleet never came out again, though Jellicoe lost more ships and men than von Scheer, the victory must be undeniably awarded to the English.

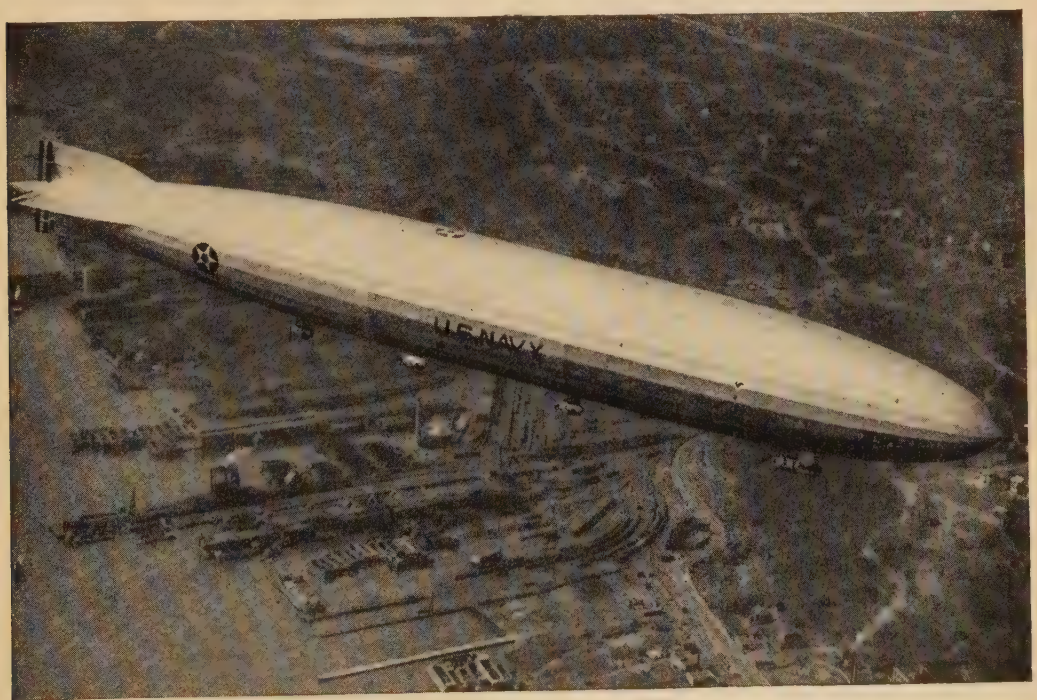
The British killed and wounded were 363 officers and 6322 men, most of whom were killed.

STRENGTH

British	*German*
28 Battleships	22 Battleships
9 Battle Cruisers	5 Battle Cruisers
33 Light Cruisers and Cruisers	11 Light Cruisers
1 Seaplane Carrier	
1 Mine Layer	
79 Destroyers	72 Destroyers

LOSSES

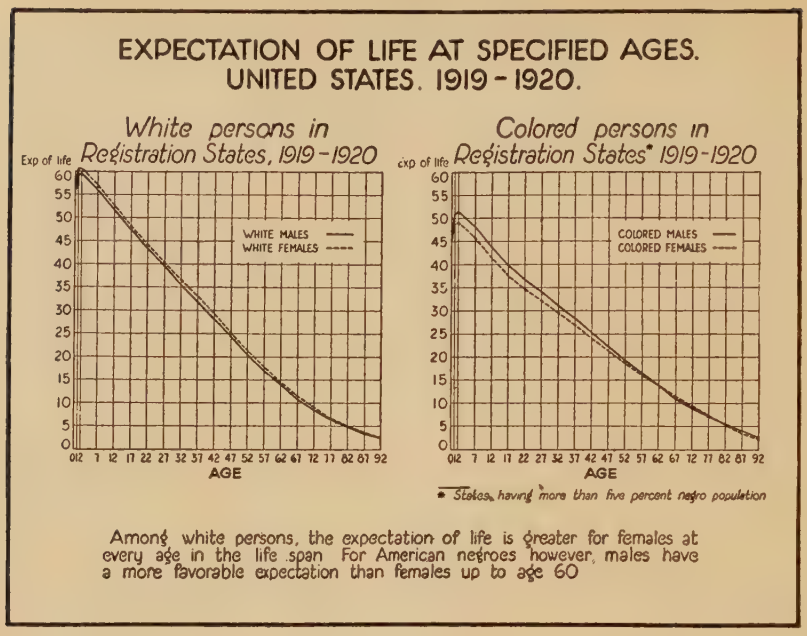
British	*German*
3 Battle Cruisers	1 Battleship
	1 Battle Cruiser
3 Cruisers	4 Light Cruisers
8 Destroyers	5 Destroyers

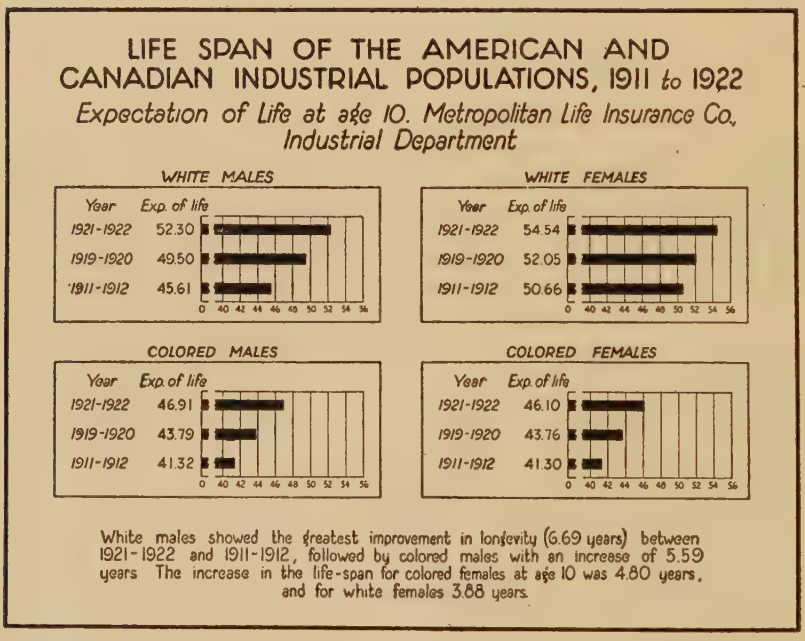


U. S. Navy Official Photograph

THE ILL-FATED UNITED STATES DIRIGIBLE *SHENANDOAH*

EXPECTATION OF LIFE TABLES


EXPECTATION OF LIFE AT SPECIFIED AGES.
UNITED STATES. 1919 - 1920.
White persons in Registration States, 1919 - 1920
Exp of life
WHITE MALES
WHITE FEMALES
AGE
Colored persons in Registration States* 1919 - 1920
exp of life
COLORED MALES
COLORED FEMALES
AGE
* States having more than five percent negro population
Among white persons, the expectation of life is greater for females at every age in the life span. For American negroes however, males have a more favorable expectation than females up to age 60


LIFE SPAN OF THE AMERICAN AND CANADIAN INDUSTRIAL POPULATIONS, 1911 to 1922
Expectation of Life at age 10. Metropolitan Life Insurance Co., Industrial Department
WHITE MALES
Year Exp. of life
1921-1922 52.30
1919-1920 49.50
1911-1912 45.61
WHITE FEMALES
Year Exp. of life
1921-1922 54.54
1919-1920 52.05
1911-1912 50.66
COLORED MALES
Year Exp. of life
1921-1922 46.91
1919-1920 43.79
1911-1912 41.32
COLORED FEMALES
Year Exp. of life
1921-1922 46.10
1919-1920 43.76
1911-1912 41.30
White males showed the greatest improvement in longevity (6.69 years) between 1921-1922 and 1911-1912, followed by colored males with an increase of 5.59 years. The increase in the life-span for colored females at age 10 was 4.80 years, and for white females 3.88 years.

The charts on this page, reproduced through the courtesy of the Metropolitan Life Insurance Company, New York, illustrate the scientific foundation on which modern life insurance is built. The first graph shows that the average life-span in the United States is almost fifty-eight years. The second traces the increase in the average length of life in Canadian and United States industrial populations from 1911 to 1922.

INSURANCE AND SPECULATION

How Economic Risks are Diminished
by Combination and Organization

THE GOOD AND EVIL SPECULATION DOES

IN popular discussion insurance and speculation are often confused with gambling. As a matter of fact, as we shall see, the individual differences and peculiarities of these three forms of activity are much more striking than are their similarities and likenesses.

Insurance is really the direct opposite of gambling. The peculiar characteristic of gambling is that it always involves the *creation* or *unnecessary assumption of risk*. If I gamble by tossing a coin or by throwing dice, I assume a risk and incur a chance of loss as well as a chance of gain in a manner that is wholly arbitrary and unnecessary. The coin need not have been tossed had I not so willed, and even if it had been tossed, I need not have entangled my personal fortunes with the outcome of the throw. In a horse race it normally happens that one horse wins and that the others are defeated. But this need not affect my personal fortunes. There is absolutely no risk to me in the outcome of any horse race unless I create the risk by betting on it.

It is not our purpose here to discuss the morality of gambling. We are merely concerned with its economic characteristics. We have seen that it is unnecessary, that it involves the creation of risks. And gambling has a further economic disadvantage. In the long run and on the average it necessarily involves *a net social loss*. The utility of gambling gains cannot offset the real disutility of gambling losses. To make the point clear, imagine that A and B both have incomes of $1000 per year. They wager one against the other $500 on the outcome of a certain event. A wins; B loses. A's income for the year is now $1500, while B's is only $500. For reasons which we have already discussed and which are so obvious as scarcely to need explanation, there is more difference between incomes of $1000 and $500 than between incomes of $1000 and $1500. Measured in terms of utility, A's gain does not offset B's loss. Unless successful gamblers are in general poorer men than unsuccessful ones, unless, in other words, gambling involves on the whole a transfer of wealth from the rich to the poor — an absurdly impossible assumption — it follows that gambling is responsible for a net social loss of utility. Gambling is not merely non-productive; it *destroys* rather than creates utility. This conclusion gains increased significance when we take account of the further fact that gambling gains are very commonly spent in a wasteful and extravagant fashion. The real costs, the hazards undergone, are forgotten. The winnings of gambling, easily got, are easily spent.

In economic analysis we thus find a strong case against gambling. And we have purposely taken no account of the fact that gambling very often weakens the moral fiber of the individual, although that fact has economic importance. Gambling makes men less inclined to the sustained and systematic effort which the work of economic production requires.

How, then, does insurance differ from gambling? Is not a fire insurance contract a wager between the insurance company and the insured? Does not the one virtually wager that the insured property will not be damaged by fire within the year,

while the other wagers that it will? The analogy implied in such questions is wholly superficial. The man who does *not* insure his building against destruction by fire is the real gambler. He is virtually making a wager that the property will not be damaged by fire. Now when a man makes a bet, and later covers or cancels it by betting on the other side, he is, in his first transaction, a gambler, but in his second transaction he is destroying or annihilating the gambling transaction. The second transaction is technically termed a "hedge". Insurance, it will be clear, is really hedging. Subjected to actual and unavoidable risks of property losses from conflagration, from hail or drought, or from theft, the man who does not seek to remove the risk by hedging, that is, by insuring, is the true gambler. In a similar way, the man who buys a life insurance policy should not be deemed a gambler. He should not be thought of as wagering that he will die within a relatively short term of years while the insurance company wagers on his longevity! In truth, of course, the actual unavoidable chance of his death subjects those dependent upon him for support to a real economic risk. Life insurance in some measure cancels or offsets that risk. It is a hedge.

The insurer not a gambler any more than is the insured

But, it may be argued, admitting that in both life insurance and property insurance, the insured should not be regarded as a gambler, is not the insurance contract always a wager so far as the *insurer*, usually an insurance company, is concerned? For the insured the risks in the case are unavoidable and necessary. Unlike the gambler's risks, they are not created nor are they arbitrarily assumed. They exist in the nature of the case. One has a choice between one of two alternatives: one may either carry the risk for one's self or one may shift the risk to an insurer. But to the insurer, we must admit, the assumption of risk is hardly necessary. Is not the insurer, therefore, a gambler? No, by reason of the curious paradox that as insurance is organized today the insurer, or the one who assumes risk, incurs little or no risk himself. Organized insurance really involves two principal elements: first, the insurance contract, by which risk is transferred from the insured to the insurer in return for a definite determined premium or price; second, the annihilation of the risks thus transferred from the insured to the insurer by their combination in large groups where scientifically predictable law, rather than chance, reigns. The blotting out of risk through the combination of risks is thus an essential function of insurance.

The law of large numbers the foundation of modern insurance

Whether a given individual will die today, a year from today or in twenty years, is a wholly indeterminate matter, even though there may be certain probabilities in favor of one outcome or another. But in a large population the number who will die in a given year is, putting aside the effects of epidemics of unusual severity, predictable with a high degree of accuracy. This will be true even of the number of deaths among men of any given age, or in given occupations. It will be true in some measure of deaths from different causes. The death rate, in a progressive community, tends to decrease slowly through the years. But from year to year it is constant enough to make it suitable for use by insurance companies. The *law of large numbers* is the foundation of insurance. In some cases the law of large numbers seems to extend down into groups that are represented by very small numbers indeed. Comparatively rare events seem sometimes to come with remarkable regularity. One example quoted in books on the theory of probability is the number of Prussian cavalrymen killed each year by the kick of a horse. For the years from 1875 to 1894 the number of casualties per year varied only between three and eighteen, and their distribution among the different army corps was astonishingly regular. So the number of suicides or the number of murders among persons, say, of a given race, in a large city, will, year after year, bear an astonishingly constant proportion to the total numbers of the population affected.

Insurance is built upon the scientific principle that the combination of disconnected, individual, chance events gives an aggregate result that is so dependable that it can be used as a practical basis of calculation. Accident insurance, fire insurance, in fact, property insurance of all kinds, have a less adequate basis than life insurance, but as experience is increased and is more scientifically recorded and analyzed, the basis of rate-making in those fields is becoming more and more definite and satisfactory.

Insurance deals with necessary risks, gambling with unnecessary

We have said above that, in order that the result should be dependable and predictable, the events with which insurance concerns itself must be separate or disconnected. This condition is highly important. A great conflagration, such as that in San Francisco, will sometimes upset the calculations of fire insurance companies. In the case of such a conflagration the losses are not disconnected; the burning of one building follows from the burning of another. In their rates, fire insurance companies take account of this "conflagration hazard", as it is called, but its amount is necessarily conjectural. So in life insurance: it may sometimes happen that a great epidemic or a great war may introduce real variations — real risk, that is — but even under these exceptional conditions, the insuring of lives remains on the whole a business attended with as little risk as almost any other under the sun. From every point of view, we may conclude, insurance, as organized today, is not gambling. It deals with necessary risks, gambling with unnecessary risks. It creates utilities by distributing and thus softening losses that would otherwise cut deeply into the incomes of millions of individuals exposed to the manifold risks of life. It destroys risks; gambling creates them.

In law, insurance always means an insurance *contract*, an agreement by means of which risk is transferred from one person to another. In economic analysis, the *transfer* of risk is not so important as the reduction of risk to certainty by means of organization and combination. It is the economist rather than the lawyer who speaks when the phrase "self-insurance" is used. This refers to the practice of eliminating risk, or rather of reducing the range of uncertainty, by a wide distribution of investments or of other property holdings. Thus a large corporation with many plants located in different parts of the country may find it more economical to "carry its own insurance". That is, it does not enter into an insurance contract by which the risk is transferred to an insurer, nor is it even necessary that part of its annual earnings should be put aside into an "insurance fund" so that there will be something in reserve to cover large unexpected losses. The establishment of an insurance fund may be in a particular case a matter of ordinary business prudence; it is not on that account necessarily a part of self-insurance. The essential things in self-insurance are the number and the distribution of the company's plants or other holdings. Serious losses from fire are not likely to occur in any one week or in one year to many of a company's plants, if they are located in different towns.

In the experience of American railroads, losses from fire and flood or from railway accidents have been found to be distributed evenly enough so that few companies have thought it worth while to establish special insurance funds. Such losses are commonly charged to operating expense and they are rarely large enough to lead to important fluctuations in earnings.

Self-insurance in not "putting too many eggs in the same basket"

In a similar way, the moneyed man who distributes his investments among many different types of securities is protecting himself by using the principle of self-insurance. Self-insurance in this case is simply obedience to the old injunction not to put all one's eggs into one basket. The use of this principle makes it possible for investors or endowed institutions, like universities and colleges, to secure a larger income than would be possible if they had to limit themselves to one or two classes of investments or securities.

By holding a good many different types and classes of securities the private investor and the institution can afford to put a certain amount of money into securities which are not of the very safest order, and which for that very reason yield a higher annual rate of return. The large investor, it is clear, will do better to put his money into securities which yield a 6 per cent return, even if he occasionally meets with small losses, rather than to restrict himself to gilt-edged securities of almost absolute soundness which yield only 4 or 5 per cent return. The principle of self-insurance finds many other illustrations in the ordinary conduct of life. A housewife, closing her home for the summer, hid her silver in different parts of the house in the hope that if housebreakers entered they would not be likely to find all of it. In so doing, the housewife was applying the principle of self-insurance.

The important difference between destroying risk and eliminating loss

These examples make it clear that when we say that insurance destroys risk, we mean not that insurance prevents loss but that it *decreases the margin of uncertainty* with respect to the magnitude of unavoidable losses. Life insurance does not prolong a man's life. It does not eliminate the economic loss which families and the community suffer when men are cut off in the prime of their productive powers. It is certain that a fairly definite number of such men will die in each successive year. Insurance does not diminish the real loss; it distributes it in such a way that what would have been the uncertainty of the individual case is merged in the certainty of the common lot. The absolute unknown chance of death of a particular bread-winner is merged in the certainty that a certain number of bread-winners will die in a given year. There is an important difference, therefore, between destroying *risk* and eliminating *loss*.

It should be remembered, however, that by eliminating risk by cushioning and distributing the effect of the blows of adverse fate, insurance really lessens the net effects of loss. In fact, any institution or any system which leads to the more equal distribution of either gains or losses increases utility, just as gambling or any other activity that tends toward a more unequal distribution of wealth diminishes the sum total of utility. While insurance, therefore, does not prevent loss, it lessens the destruction of utility which accompanies economic loss.

Speculation gets a much worse reputation than it always deserves

We now pass from the subject of insurance to that of speculation. Is speculation merely a species of gambling? Is it, like insurance, gambling's opposite? Or is it neither one thing nor the other? Popular hostility and distrust of speculation are undoubtedly widespread. In the minds of many people the speculator is a gambler. The worth and value of insurance — the joint product of science and of business enterprise — has come to be accepted by the community: not so with speculation. Not only is it commonly classed with gambling, but it is charged with responsibility for all sorts of economic losses. The consumer holds that speculation is responsible for the fact that prices are high; at the same time the farmer is likely to be blaming it because prices are low. The business man and the banker are likely to shift to the speculator blame for the crises which recurrently work havoc in modern industry and finance.

Now it must be admitted at the outset that there may be some truth in such charges. But on the whole, they are more nearly false than true. The individual professional speculator is often a gambler, in the sense that he conducts his transactions in the gambling spirit. This adverse characterization is by no means true of all speculators, some of whom are scientific students of economic and financial conditions. But even if all speculators were as individuals no better than gamblers, it would hardly be fair on that account to bring a wholesale indictment against the institution of speculation itself. We are not concerned here so much with the morals of the individual as with the general and economic aspect of an institution.

The two essential differences between speculation and gambling

From this point of view, what are the essential differences between speculation and gambling? They are two. In the first place, as we have seen, gambling involves the creation of unnecessary risks. Speculation, like insurance, has to do with risks that exist in the nature of the case. The second difference is that gambling does not alter or affect the outcome of the event which is the subject of the wager. In an honestly conducted horse race the best horse will win whether or no he happens to be a favorite in the betting. The fact that a coin is to pass into the possession of a person who correctly guesses how it will fall after being tossed in no way affects the outcome of the toss. Speculation, on the other hand, actually affects prices. That is, it affects and in part determines the outcome of the particular event with which speculation is concerned. This will be made clear if we pause to consider the distinction between speculation and bucket-shop operations.

The distinction between speculation and bucket-shop operations

The operator of a bucket-shop usually maintains, to outward appearances, a broker's shop in which actual speculation involving actual buying and selling is conducted. The difference is that the operator of a bucket-shop does not execute the orders given him to buy and sell certain securities. He merely records these orders and pays his customers the gains and collects from them the losses which would have been theirs if the orders had been actually executed. In other words, the bucket-shop proprietor merely bets against his customers. He conducts a gambling establishment in which the gamblers are betting on the prices of commodities or securities instead of on the outcome of horse races or on the turn of a roulette wheel. The bucket-shop operator has a margin or advantage as against his customers in that he charges them a commission such as a reputable broker would charge on actual transactions. In addition, the bucket-shop operator knows that on the average his customers are more likely to be wrong than right and, moreover, he is sometimes able shrewdly to guide their operations so that they will be to his own ultimate advantage. It is unsafe to do business with a man whose profits come from your mistakes.

Turning to actual speculation, we find an entirely different state of affairs. Legitimate speculative transactions are actual and legally enforcible purchases and sales. As such, their influence on prices is precisely like that of any other purchases and sales. Speculative purchases and sales enter into and constitute part of the actual supply and demand of the market. It is on this very account, however, that speculation is sometimes condemned! Its influence on price is said to be unwholesome, arbitrary and in general disturbing. Let us examine some of these allegations and try to see what truth there is in them.

Some of the allegations against speculation in influencing prices

Take, for example, the common charge that speculative supplies of commodities — supplies which are added to the actual physical products available for the market — force prices down to an unduly low level. This kind of complaint is likely to come, in all honesty, from farmers and cotton growers who sometimes feel that the profits of their own toil go in large measure not to themselves but to speculators, whom they consider, therefore, to be merely economic parasites. Such critics are prone to point to the fact that the volume of wheat or of cotton sold by speculators is generally very much greater than the number of bushels of actual wheat or pounds of actual cotton available. It is this surplus or speculative supply which pushes the price of such products down to an unprofitable point, they say.

The error in this criticism is that it fails to take account of the fact that each speculative sale is accompanied by a purchase. Just in the measure that speculation increases supply, so also, in the same measure, it inevitably increases demand. We do not refer to the fact that all of the cotton

or wheat that speculators sell on any given day must in some way find buyers, for it is easily possible that in order to induce persons to buy the quantities offered, if these happen to be very large, prices must be forced down for the time being to a low point. The important fact is that every speculator who sells wheat today must either have previously purchased it or he must purchase it later to cover his sale. Take, for example, a speculator who sells wheat today because he believes that the price is going to be lower later on. In such circumstances, the speculator might enter into a contract to deliver wheat two months from today. By his very selling operation, therefore, he has virtually committed himself to buy an equivalent amount of wheat within the next two months. His selling operations today may somewhat depress the price of wheat; his buying operations later on will in all probability have a corresponding tendency to raise the price.

In the long run speculation cannot affect general trend of average prices

There is no necessity for pushing this analysis much further. The fundamental point is simple and obvious. In the long run, through a period of successive years, speculation cannot possibly affect the general trend of the average price of wheat or of cotton or of any other commodity. So far as speculation affects prices at all, its force is spent in determining the *variations* or movements of prices in shorter periods of time, that is, in successive weeks or months, or of successive days. Whether the average price of cotton at the end of the third decade of the twentieth century is higher or lower than was the price of cotton at the beginning of that century is a fact wholly outside of the range of influence of speculation. The sole determinants are the actual supply and demand of the ultimate producers and ultimate consumers of cotton. But if we were to trace a diagram of the fluctuations of the price of cotton from 1901 to 1930, we should undoubtedly find it necessary to attribute many of the particular fluctuations or undulations of the line of prices to the effects of speculation.

The further question at once suggests itself: Is the general effect of speculation upon the variations of prices wholesome or harmful? Does speculation tend to make prices more stable or more variable?

Tendency of prudent speculation to diminish variations in price

We are not yet ready to attempt a full or definitive answer to these questions. But of one thing we may be fairly sure: if speculators were, in general, well-informed and prudent in their operations, the net effect of speculation would diminish the variations of prices. This follows from the simple fact that so far as the speculator can foresee probable changes in prices, and just so far as he acts accordingly, just so far will his operations tend to eliminate those very changes. Suppose, for example, that the present price of wheat is $2 a bushel, and suppose that the general conditions of suppy and demand are such that, in the absence of speculation, the price would inevitably drop to $1.50 per bushel at the end of three months. Imagine, now, that speculators, by careful market observation and analysis, have determined these facts and that they act accordingly. Using the mechanism afforded by contracts for future delivery, they will sell wheat today with the expectation of buying wheat later, say, three months from today, at a lower price. Now it is clear that this speculative supply, as it is called, coming into the market today, will lower the price considerably below $2 per bushel, while the purchase the speculators make later will increase the price of wheat three months from now to considerably more than $1.50 per bushel. In general, it is fair to say, these speculative operations will virtually move wheat from a time at which the demand for it as indicated by its price is relatively low, to a time at which the demand measured in terms of price is relatively greater. In so doing, of course the speculators will have performed a public service not only to agriculturists but to the consumer as well. When the price of wheat is low, some part of the supply may be devoted to relatively unimportant uses; when the price of wheat is unduly high,

inconvenient and irksome economies may be necessary. By smoothing out the differences in prices of wheat at different periods, speculation tends to distribute its consumption in such a way that the best use is made of the aggregate supply. Speculation cannot alter the number of bushels of wheat in the market. But by operation upon the price of wheat, it may distribute the consumption of wheat in such a way that the utility of the total supply is increased. This is one of the ways, but only one of the ways, in which the speculator, so far as he operates wisely and shrewdly, is in reality a producer of wealth.

How every business man is a risk taker and therefore a speculator

Another of the beneficent results of organized speculation is that it makes it possible for those members of the community who are unwilling or unable to bear the burden of economic risk to shift such burdens to the shoulders of men whose business it is to assume them. *The speculator is a specialist in risk taking.* Risk in some form or another is found in all modern industries. In fact, from one point of view, it is wholly proper to say that every business man, every profit seeker, is a risk taker and therefore a speculator. He speculates, we may say, with respect to the kind of goods that the market will demand and the prices which the market will pay. He speculates with respect to the operations of his competitors and their effects upon his own business. In a host of other ways, too, he takes unavoidable risks. Some of these risks are inseparable from the business man's operations. Some of them he may get rid of by transferring them, as we have said, to professional speculators.

How the manufacturer transfers some of his risks to professional speculators

Take, for example, the cotton manufacturer. The price of cotton fabrics, especially of the cheaper grades, necessarily fluctuates as the price of raw cotton fluctuates. In securing his annual supply of raw material the cotton manufacturer incurs the risk that, after he has bought, the price of raw cotton will drop to a lower point, that the price of his own product — cotton fabrics — will therefore fall and that he will incur large losses. If, on the other hand, it should happen that the price of raw cotton should rise, the manufacturer would gain by reason of the fact that he could sell his manufactured fabrics at a correspondingly higher price. But ordinarily the cotton manufacturer does not wish to subject himself to these particular risks of loss or gain. He is a manufacturer, not a professional speculator. He desires to devote his time and attention to the manufacturing and selling of cotton fabrics and, of course, he wants to secure such profits as he can get from those operations. He is not in a position to incur the chance of large losses from an adverse turn of the cotton market, even if there is an equal chance of correspondingly large gains. He prefers to pass these particular risks over to the speculator. He accomplishes this by the device known as "hedging." When he purchases raw cotton for his mills, he *sells* in the speculative market through a cotton broker an equal amount of cotton or of contracts to deliver cotton. Then as rapidly as the raw cotton in his warehouses is made up into finished cotton goods and sold at prices which are in large part determined by the then prevailing price of raw cotton, he *buys* an equivalent amount of cotton in the speculative market. When his stock of raw material is finally disposed of, he will have bought sufficient cotton through his broker to cover or offset all of the engagements to deliver cotton that he entered into in the speculative market at the beginning of his speculations. Any profits that he might otherwise have made from a possible rise in the price of raw material are offset by corresponding losses on his speculative transactions. On the other hand, the losses which he would have suffered if the price of raw cotton had dropped have been offset by the profits on his speculative transactions. He has freed himself from the purely speculative risks attending the buying and selling of cotton at the relatively small expense of the commissions he has had to pay his broker. Dealers in grain and other produce, millers and

men in other industries are able, by hedging, to restrict their own chances of profit and loss to those necessarily connected with their business operations. The chances of loss or gain resulting from *price changes* are shifted to other shoulders.

There is no doubt that by the facilities it offers for hedging speculation performs a real service to many producers and dealers. This service, however, would not suffice to justify speculation if it were true, as some claim, that speculation itself is primarily responsible for those ups and downs in prices which are primarily responsible for business losses and for general business disturbances. One could hardly justify speculation on the ground that it affords facilities for hedging if it were true that the necessity for hedging or protecting one's self from the effects of unforeseeable price fluctuations were itself something for which speculation is responsible. We must return, therefore, to the problem of the effects of speculation upon the stability of prices.

Actual short-time fluctuations of markets originate in speculation

We have seen that in the nature of the case it can have no possible influence upon what we call the long-time trends of prices. For example, the general level of prices in the United States in 1913 was about 30 per cent higher than the average level in the decade from 1890 to 1900. Speculation did not and could not have had anything to do with this general change. At the other extreme, we find fluctuations in price which are of extremely short duration. Thus the price of wheat or of cotton or of the shares in a large corporation changes not only from week to week but from day to day and from hour to hour. These short-time fluctuations are in many cases the effect of speculative buying and selling. It is very likely that without organized speculation, that is, without stock exchanges and produce exchanges, short-time variations in price would remain, and, judging by past experience, it is likely that they would be more erratic and violent even than under speculation. But the fact remains that the actual short-time fluctuations of present-day markets originate in speculation. They are the results of the uneven operation of the forces of supply and demand, and in the modern market those forces very largely take the form of speculative buying and selling.

Tendency of organized speculation to correct seasonal price variations

But there is yet a third type of price variation and, from some points of view, the most important of all. There are variations not only from hour to hour, and from decade to decade, but from month to month and season to season. There is no doubt in the minds of competent and careful students of the problem that organized speculation in staple commodities reduces the range and the severity of these intermediate or seasonal variations in price. If it were not for speculation the price of wheat and cotton would be exceedingly low just after the harvest season, for demand would be small and supply would be large. Higher prices a few months later would be a comparative certainty. Some persons, it might be thought, would take advantage of the low prices of the harvest period and would buy commodities then and hold them for higher prices later on. This is true. But such operations *are* speculation. There is little doubt that farmers are able to get vastly more for their crops immediately after the harvest than would be the case if it were not for the great open markets where organized speculation is conducted. There market specialists buy and sell wheat and cotton and other commodities always with the constant purpose and effect of securing profits by taking advantage of any foreseeable variations in prices. Just so far as the variations they expect are real, just so far will such speculative buying and selling have the effect of reducing or eliminating them.

As a matter of fact, it is probably a sounder criticism of speculation to say that it too frequently *over-discounts* changes in price. Not only does it eliminate them, but it even in many instances reverses them! The competition of speculators may go so far that what would have been a period of falling prices may be turned into one of ris-

ing prices. It is likely, however, that this does not happen so frequently or on such a scale that it gives the basis for a really serious indictment of speculation.

More speculation than is necessary to accomplish best results

A more serious criticism is implied in the fact that there is vastly *more* speculation than is necessary to accomplish all the good that speculation can possibly do. In particular, there is too much uninformed, inexpert speculation; there are too many transactions which are conducted merely in the gambling spirit, or by men who are induced by "tips" and rumors to venture their money in losing operations. The speculation which accomplishes good is based upon expert and scientific analysis of economic tendencies. The speculation which does harm is that which is conducted by the ignorant and the ill-informed and, we must add, by the wealthy man who plays the game with loaded dice. When the large speculator plays with loaded dice, it is usually in one of two wholly different ways. He may be making use of inside information which is his as a director or officer of a corporation, — virtually, that is, as trustee for the stockholders. In such cases, he should be held accountable to them for his profits. Or he may make use of the sheer power of operations conducted on a large scale to crush the small fry who are in the market, and to manipulate prices for the time being to fit his own ends. No man is so wealthy that he can permanently depress or inflate the market for a particular commodity or security by buying or selling on large scale. But financial power does make it possible to manipulate artificially the prices of commodities or of securities for the time being. In this evil, as yet unremedied, there inheres one of the principal defects of speculation as conducted today.

Foolish condemnation of dealing in futures, a necessity of modern business

Speculation is sometimes condemned on absurdly foolish grounds. Thus we sometimes hear it said that "dealing in futures" is something especially to be condemned. Future wheat and future cotton seem to be non-existing myths; trading in them has an appearance of unreality. Yet a moment's thought will show that modern industry is impossible without dealing in futures, and that the system of dealing in them permeates almost every nook and corner of modern business. The contractor who agrees to build a house for you at a stated price is dealing in futures. The steel mill which takes an order for rails or for structural steel is dealing in futures. Banking transactions almost without exception involve dealing in futures. The workman who accepts employment is dealing in futures; he is making a contract for the future delivery of his services. Some state legislatures have made fruitless attempts to prohibit dealing in futures. Any systematic and logical attempt to put such a prohibition into force would absolutely stop the wheels of industry.

Criticism of speculative buying and selling as not real, delivery being seldom made

Again, it is sometimes urged that speculative buying and selling are not real buying and selling because it rarely happens that actual delivery is made in fulfilment of speculative contracts. Now it is perfectly true that the amount of speculative purchases and sales is enormous as compared with the amount of commodities actually delivered, but the explanation is, of course, that through a *clearing* system speculative purchases and sales are canceled one against another — just as credits and debits are canceled on the books of a bank or in a bank clearing-house. Suppose a man buys a hundred thousand bushels of wheat for delivery two months later and then, within the intervening period, agrees to deliver a hundred thousand bushels at the same date. Let us suppose that A has bought from B and has sold an identical amount to C. Is the transaction less real, is it in any way tainted with immorality, merely because A, instead of taking delivery from B and turning the goods over to C, instructs B to make delivery directly to C, A merely paying his losses or receiving his profits on the transaction as the case may be? The clearing

methods used in actual speculation are merely an enlarged application of this principle. In a group of twenty-six men whom we may represent by all the letters of the alphabet, it may happen that A is the only ultimate buyer and that Z is the only ultimate seller. Is there any reason why the commodities should change hands twenty-five times instead of being transferred directly from Z to A?

"Short-selling", the only effective bear move to influence market prices

Again, there are some critics of organized speculation who would prohibit "short-selling". On the produce exchanges, and in general on all of the exchanges of Europe, short-selling takes the form of contracts for future delivery entered into before the seller has bought the commodity or security which he has agreed to deliver. On the stock exchanges of the United States, a short sale is not a contract for future delivery, for actual delivery is made of securities borrowed for the purpose. To prohibit short-selling would be to weaken greatly the supply of "bear" side of the speculative market as compared with the demand or "bull" side. Thus the bears in the market who honestly believe that present prices are too high and that decline is imminent would have no effective way of utilizing their judgment in the market in such a way as to influence prices. The general aspects of short-selling are already covered by what we have said about dealing in futures. It is found not only in speculation but in business transactions of every imaginable type.

Exaggeration in fluctuation due to highly inflated bull market

We return to the fundamental fact that the peculiar difficulty with speculation is over-speculation. Too many men speculate on too slender a fund of information. One of the bad results of over-speculation is that the necessary ups and downs of prices are sometimes exaggerated. In the stock market, for example, when prices begin to move upward and especially when some speculators have made spectacular profits, outsiders are attracted to the market and buy, usually with no better basis for their buying than their belief that, since prices have gone up, they must continue to go up! The increased buying of outsiders who are always attracted into a rising or bull market further stimulates the rise of prices. The apparent profits made from the continuing rise are reinvested in yet further purchases which put prices higher and higher. The net result is a highly inflated bull account or, in less technical language, a tremendous volume of over-purchasing.

Of course, just as soon as, for one reason or another, prices begin to decline, some men sell in order to realize their profits before it is too late, while others are forced to sell because the decline in values makes it necessary for them either to sell or to deposit more money as security for the broker who is acting as agent for them or the banker who has advanced funds. As a result of such selling the decline of prices is likely to be even more spectacular and precipitate than was their rise. Thousands of men lose money and many industries are likely to be severely shaken. The few who profit are wise professional speculators who have seen the same thing happen again and again and who have learned to profit by discounting the mistakes of the majority.

Speculation in stocks more dependent on money market than that in produce

These speculative swings are more common and more violent on the stock exchange than on the produce exchange. This is partly because speculation in stocks is much more closely dependent upon the condition of the money market than is speculation in commodities. This, in turn, is due to the American system of forbidding contracts for future delivery on the stock exchanges. When, as on the produce exchanges of the United States and on the stock exchanges of Europe, contracts for future delivery are permitted, a much larger volume of transactions are canceled or offset one against another. When immediate deliveries have to be made, as in the case of sales on the New York stock exchange, and when the speculative purchaser

has to receive and pay for his security at once, there is certain to be an enormous demand for bank loans with which to finance these purely speculative transactions. In the United States, speculation, and especially stock speculation, is carried on with borrowed money to a larger degree than it is in any other country. This is one of the factors which undoubtedly is responsible for the speculative excesses we have already mentioned. Speculation is too closely allied to the money market; it is too sensitive and responsive to interest changes and discount rates. In turn, purely speculative changes react on general conditions in the money market and thence necessarily upon the general condition of industry. It is only fair to say, however, that since the inauguration of the federal reserve system many of the worst evils arising from the connection between the money market and speculation have been removed. But the fact remains that call or demand loans on speculative securities occupy a relatively larger place in New York than anywhere else in the world, and that the influence of this type of loan, subject as it is to a highly variable interest rate, upon speculation and the banking situation, is not wholesome.

Produce exchanges about only example today of perfect competition

Thus, we see that, despite the good that speculation really accomplishes, there remain real evils attached to it. Some of these, perhaps, are part of the price we have to pay for its benefits. Others can and should be remedied. We should not allow the presence of these admitted evils to obscure the fact that speculation performs a number of important economic functions. On the whole it exerts a stabilizing influence upon price, and in particular it reduces what we have called the seasonal variations of price. It makes it possible for the risks arising from price fluctuations to be shifted to a class of professional risk takers. It provides open markets in which, despite the occasional presence of short-lived attempts at manipulation, prices are determined in the long run by the powerful play of competitive forces. There are no more perfectly competitive markets, no markets in which the forces of supply and demand fix prices more definitely and accurately, than are furnished by the great organized produce exchanges. In fact, they afford about the only actual illustration of that "perfect competition" which is otherwise met with only in economic theory.

How great an advantage it is to have open and uniform prices, we are all in these days too likely to forget. Consider the position of an investor desiring to purchase shares in a certain corporation. Without the open speculative market there could be no insurance that the price he is asked to pay for a particular share is a fair price. There would be no single market price. Men would have no real standard by which to measure the value of their holdings. They would be operating in the dark while now they operate in the light that open markets afford. Sometimes the light is a little dim, sometimes it does not shine as steadily as it might. But there is scarcely any other area in the whole wide field of economic life that is so well illuminated, as are the great organized speculative markets.

THE TAMED WORM THAT CLOTHES THE RICH

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A MULTITUDE OF SILKWORMS FEEDING UPON MULBERRY LEAVES AT SHIZUOKA, JAPAN

THE SILK INDUSTRIES

The Amazing Results of the Taming
of a Moth Five Thousand Years Ago

THE STRIFE OF SILK-FARMER AND CHEMIST

MAN has tamed many creatures to his uses, but the strangest and most curious of his essays in domestication is that of the silk-moth. For about five thousand years an insignificant and feeble moth, about half an inch in size, has been kept working to make clothes for mankind. It has been robbed of its natural strength, so that it can scarcely fly, and would certainly perish if it returned to its native forests on the Himalayas. It is fed by hand, in light, airy, sheltered rooms; it is protected from disease by troops of human guardians armed with microscopes; and almost from the dawn of civilization mates have been chosen for it with more care than parents select husbands and wives for their children. No race-horse, no prize-winning cow, has been bred so carefully as has the silk-moth for many thousands of years. It has almost been refined out of existence by extreme domestication, for it has grown so feeble that the condition of its health has had serious effects upon the industrial life of great modern nations. And men of science are still busy trying to find some wild silkworm that will resist disease, and yet produce as fine and abundant a silk as the tamed variety does.

Every year the tiny moth is said to produce more than $300,000,000 worth of silk. But this is probably an under-estimation of its extraordinary powers. For the amount of silk that the Chinese consume themselves is probably very much greater than that which they export. The silk-moths in Europe alone are reckoned to produce annually thread to the value of $15,000,000; and it is probable that the total production of the silk-moths in China and Japan comes to double this amount. Had it not been that towards the middle of the nineteenth century the moth had been so weakened by its strange artificial industrial life that it was almost swept clean out of existence by the attack of a microbe, India would now be a great silk-producing country, and so would France. But at the present time Italy, China and Japan are unrivaled for the productiveness of their silk-farms. India is still fighting against the silk-moth microbe; France has given up the struggle; while a number of scientists at Trent have been making a strenuous attempt to convert the poor, weak little moth into one of the principal workers in the villages of Tyrol.

Recently a new silkworm has been discovered in Dalmatia. It feeds on the leaves of oak-trees, and the fiber of its cocoon is said to be more abundant, finer and whiter than that of the common tamed silk-moth. On the other hand, a wild variety of the domesticated creature has been found on the wooded heights of the Himalayas; so it is thought that these mountains were the original home of the wonderful little thread-maker that the Chinese captured on some mulberry-trees some time before 2640 B.C., and removed forever from its native woods.

The achievement of the patient and ingenious Chinese was really extraordinary. Very likely they began by collecting the wild cocoons, as some of the jungle races of India still do. They never search the trees, for it would be impossible continually to climb to the tree-tops in the hope of finding there a full-fed caterpillar that had completed its task of weaving a cocoon.

The silk-hunters begin by searching the ground for droppings made by the caterpillars, and only when these are found do they climb the trees. If they are fortunate they may find some cocoons still unbroken; but very often the moth has escaped, leaving behind it only the ruins of the little silken house it made to shelter itself from foes while it was changing from an ugly caterpillar into a winged creature of the air. Perhaps it was after a disappointment of this sort that some Chinaman took to collecting the tiny eggs of the silk-moth, and keeping them until the caterpillars were hatched, and then feeding the caterpillars — or silkworms, as they are usually called — on the leaves of the white mulberry tree. But an infinite amount of care and labor was necessary before the wild moth was developed into the marvelous little domesticated spinner which the Empress Si-Ling-Shih first made famous by breeding it herself in the imperial palace. This was in the legendary ages of Chinese history, and legend attributes to the empress the invention of the loom for weaving silk into the beautifully patterned webs which thousands of years afterwards sold for their weight in gold in the Roman Empire.

THE SILK-MOTH

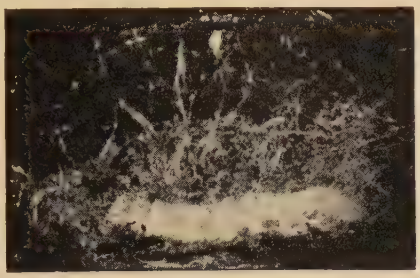
By this time the silk-moth had become a great source of wealth to the Chinese nation, and there was a general conspiracy to keep the origin of silk a secret from all foreigners. Inquisitive strangers were told that the beautiful material was obtained from the fleeces of sheep, which at certain seasons of the year were sprinkled with water in the sunshine to promote the growth of their exceptionally fine wool; and when this fine wool was combed out it was silk ready for weaving! But about sixteen hundred years ago the Japanese and the natives of India managed to discover the secret. The Japanese despatched a secret mission to China, and obtained some silkworms, and induced four Chinese girls to return to Japan and teach the people how to look after the wonderful moths. The people of India conducted their campaign in a more romantic manner. The son of one of their kings wooed and married a Chinese princess, and the bride concealed some of the eggs of the silk-moth in her headdress, and on arriving in her husband's country taught his people the art of sericulture. Two and a half centuries afterwards two Persian monks of the Nestorian school of Christianity traveled from China to Constantinople with some eggs hidden in a hollow cane, which they presented to the Emperor Justinian. From the precious contents of their bamboo tube, brought to Europe about the year 550 A.D., were produced all the generations of silkworms which stocked the Western World, and gave trade, prosperity and untold wealth to great communities for thirteen hundred years.

THE MOTH'S EGGS AS THEY APPEAR UNDER THE MICROSCOPE

A SILKWORM SPINNING

Only a few years ago the Japanese tried to preserve the secret of a new kind of silk for which their country was becoming famous. When the silk-moth plague broke out in Europe and Asia, towards the middle of the nineteenth century, Japan was one of the few countries still unaffected. It was from the sound eggs of her silk-moths that the silk-farms

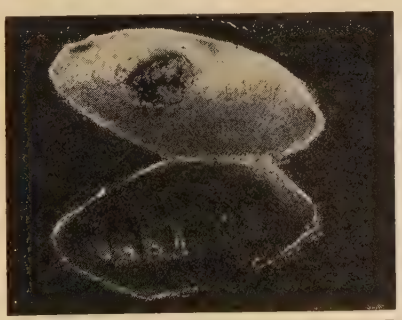
of Italy and Switzerland and France were restocked. But the Japanese had also discovered a big wild moth in their own forests — six inches across the wings, and of a bright yellow color — which wove a large cocoon. The moth fed on oak-leaves, like the wild tusser silk-moth of the Indian jungles of central and southern India, but the thread of the Japanese moth was much finer and more lustrous; it was said, indeed, to be superior to that of the Chinese moth. So no eggs were allowed to be sent out of the country. These, however, have now been obtained, but the art with which the Japanese breed and rear the moths still seems to be beyond the reach of the silk-farmers of India.



THE COCOON BEING SPUN

Until the moth plague broke out, the silk-farms of India promised to outrival those of China itself. For the domesticated Indian moth had developed a strange and valuable quality in its new tropical home. In temperate climes the moth breeds only once a year; in India the silk-farmer had four crops in twelve months. Now, however, he generally loses two entire crops every year, through the same plague that started in France in 1849, and spread throughout the world. It raged unchecked until 1866, when Pasteur discovered the microbe that produced it, and showed how sound eggs and healthy breeds could be obtained by the microscopic examination of the moths. Unfortunately, the small Hindu cultivators will not adopt the scientific method of protecting their stock. So their wonderfully prolific mulberry silk-moths are perishing; and most of the silk now produced in India is obtained from the tusser oak-feeding wild moth that spins an inferior kind of silk thread that is strongly impregnated with tannin.

THE COCOON BEFORE AND AFTER THE ROUGH SILK IS REMOVED



A COCOON CUT OPEN, SHOWING THE CHRYSALIS WITHIN

The eggs of the silk-moth somewhat resemble turnip-seeds. There are about a hundred to a grain's weight. From an ounce of eggs and one ton of mulberry-leaves there are produced 140 pounds of cocoons, yielding about twelve pounds of raw silk. Very often the eggs are kept in cold storage to prevent them from hatching out before the mulberry-trees leaf in spring. This seems to have been done from time immemorial in China, by placing the eggs in jars partly immersed in a stream of cold running water; but in Europe refrigerating machinery is used. Again, when the mulberry-tree is putting forth its tender foliage, it is necessary in many countries to use incubators to hatch the eggs quickly and in a regular manner. Artificial incubation has always been a most important process in the rearing of silk-moths; and both Asiatic and European silk-farmers used to tie from one to two ounces of eggs in a small silk or cotton bag, and carry this about their person and next to their skin for three days. At night-time the silken bag was placed beneath a box under the warm pillow in the bed of the breeder. On the evening of the

third day the bag was emptied into a wooden tray, on which some shredded mulberry-leaves were scattered, and again placed beneath the warmed pillow, and in the morning the tiny little caterpillars began to break out of their shells. Then, on top of the hatching-box, a sheet of paper, full of large pin holes and lightly covered with shredded mulberry-leaves was placed. The tiny caterpillars crawled through the holes, and fixed upon the leaves, and when these were almost black with the creatures they were gently raised and placed upon feeding-trays. This method is still followed by Oriental nations, but in modern silk-farms much trouble and loss in broken eggs are saved by using artificial incubators. But it says much for the ingenuity of the Chinese race that they managed, four or five thousand years ago, perhaps, to devise both a simple cold-storage treatment and a kind of artificial incubation.

PICKING MULBERRY-LEAVES IN A GROVE

The domestication of the silk-moth involved problems of rearing far more difficult than the breeding of cattle and horses and sheep; and the manner in which the problems were surmounted is evidence of the patience and inventiveness of the Chinese mind. And when the Chinese begin to coöperate in a large way, as they already have in a small way, in the progress of modern science, this extraordinary patience and regard for little but important things will probably make them admirable in the most exquisite and laborious methods of scientific research.

It is also to the Chinese that we owe the cultivation of the white mulberry-tree, on which the silk industry largely depends. The ordinary mulberry-tree that is grown for fruit is not so valuable in silk-farming as the one that produces small and useless berries. The trees must be cultivated only for their leaves, and they must be fed with plenty of rich manure in order to develop their foliage as early as possible. Young trees, three or four years old, are best, and about five hundred of them will grow well on an acre of ground. Each tree should yield not less than twenty pounds of leaves in a season. This is enough to feed a hundred silkworms, which will produce about a pound of cocoons; from these about two ounces of the best silk may be reeled, and the remainders of the silk-cases can be combed out like cotton and made into spun silk, which has about half the value of the natural silk thread.

At the beginning, the task of feeding the tiny caterpillars is easy, provided they have been hatched out in considerable quantities at regular intervals. Each tray of silkworms, on the open shelves of the silk-farms, must be of the same age, so that they will all go through their processes of growth and their work of silk-spinning at the same time. When this has been arranged by means of cold storage and artificial incubation, the worms can be handled in a wholesale manner, without having to be touched and picked up singly by the farmer. Practically all that is needed is a warm and yet well-ventilated room with

open shelves on which the food can be placed without disturbing the little creatures. At first the worms will occupy a very small space on the shelf, but as they grow larger they must be induced to scatter by spreading their food more widely. Young, tender leaves must at first be shredded for them, and served to them morning, noon and night. And as disease

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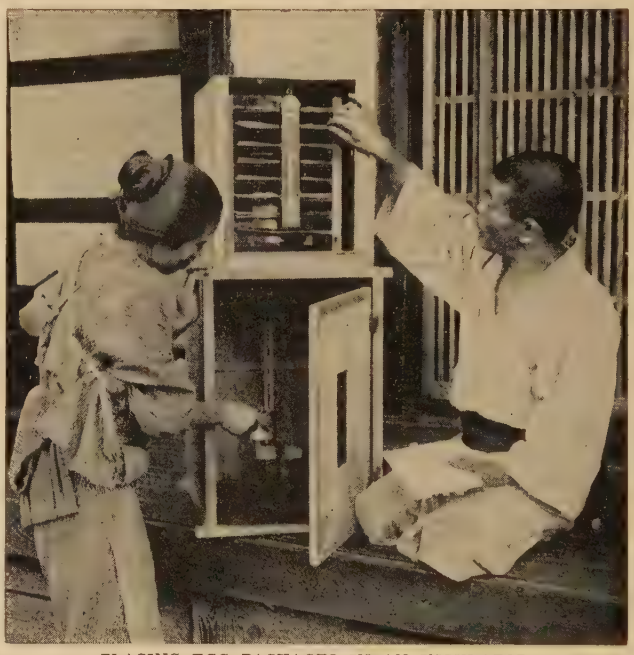
THE MULBERRY-TREE THAT WAS INTRODUCED INTO EUROPE FROM THE FAR EAST TO FURNISH FOOD FOR THE SILKWORMS

is produced if the leaves are damp, they must not be gathered with the dew upon them, or after a rain. So it is best to keep in hand a couple of days' supply of food, to tide over the exigencies of bad weather in the mulberry plantation.

Four times in the course of their brief life the caterpillars fast for some days. In these periods of apparent rest they slough off their skins, and in about a minute they appear in a new and larger coat. In this way they grow at last to the size of about three inches. The time they take in passing through their four moltings depends upon the warmth of the season and the climate. In Japan each period is about five days long, excepting the first, which is about seven, and the last, which is about ten. It is after the last molting that the labor of the silk-farmer grows really hard. The caterpillars must be fed late at night and early in the morning and several times during the day, and great attention must be given to the quality as well as the abundance of their food. For they are now amassing the material which they intend to spin into silk. Air and light must be freely admitted into the room, and the

great litter that the worms now make must frequently be cleared away, and all their surroundings kept neat and clean.

Having arrived at their utmost growth of two and a half to three inches in length, the caterpillars will cease to eat, and crawl about the shelf, searching with outstretched heads for a nook in which to spin. The spinning-places are provided by the farmer in a number of ways. Often a screen of interlaced twigs is erected around the shelves, the space between the twigs being so arranged that the little spinner need not waste much of its silk in hanging its cocoon among the branches. Little tubes of hollow bamboo or paper are also furnished by some silk-farmers, to save the spinner the trouble of making a web among the twigs. In China large mats are placed by the shelves, the whole surface of the mats being covered with curled strips of material that form spiral rounds, about an inch apart. Between these rounds the worms spin, without wasting any of their floss in making a kind of airy scaffolding to support their silken house.



PLACING EGG PACKAGES IN AN INCUBATOR

On finding a fit place, the silkworm begins its work by spinning some thin and irregular threads to uphold the future structure. Upon these it forms on the first day a kind of oval of a loose texture, called the "floss silk"; and within this oval, in the next three days, it fashions the firm and valuable ball of silk. It always remains on the inside of the ball, and there, resting on its hind part, it fastens and directs the thread with its mouth and forelegs. The thread is not fixed round and round on the inside of the ball, but is spun backwards and forwards in a wavy figure; and this is why a ball, in reeling off its silk, will not often turn round once while ten or twelve yards of thread are being drawn out.

Twenty-four hours after beginning to spin, the little worker is hidden from view; and in from three to five days it finishes its cocoon, in shape and size somewhat like a pigeon's egg. By this time the industrious caterpillar has lost half its weight and shrunk to half its size. Housed in an egg-shaped lodge, it molts for the fifth time and changes into a chrysalis, shaped somewhat like a kidney bean, but pointed at one end and having a brown, smooth skin composed in rings, with its cast coat lying inside the ball with it. Left to itself, the chrysalis molts for the sixth time, and softens with a liquor from its mouth one end of the cocoon, and then loosens and pushes aside the wet silk, and emerges as a small, white, feeble moth. If it is a female, it has scarcely the strength to flutter its wings.

It is fairly easy to select about an equal number of males and females for breeding purposes, as their cocoons are differently shaped. The creatures live but for a few hours, and are so feeble that they have to be mated by the silk-farmer. Each female moth lays from three to four hundred eggs, and then dies shortly after its partner. The eggs are collected and examined, and then put in cold storage for the spring.

At the Bacological Institute of Trent three hundred women are employed night and day in catching the moths in cells of gauze or waxed paper as they emerge from the cocoons. The cells are hung from the ceiling, and in them the moths lay their eggs and die. About three million cells are used, and from them are obtained twenty-five thousand ounces of eggs. Some women open the cells, some remove the dead moth and crush it for examination by forty women armed with microscopes. If no sign of disease is found, the eggs are kept in the Institute through the winter, and in April they are taken out of the cold storage room and distributed to customers in the villages of Tyrol.

This is the way in which all the silkworm seed of a country should be obtained. A central breeding-station, with its scientific appliances, is able to keep the national stock of silk-moths free from microbe attack. Moreover, by conducting its operations on a large scale, it can sell the seed at a very low price. The Trent Institute, for instance, sells its seed at one-third of the ordinary cost. It buys selected cocoons from the breeders, brings a few of them rapidly to maturity in incubators, and thus tests the quality; and if this is satisfactory the bulk of the cocoons is placed in boxes, and the chrysalises are there allowed to develop in a normal manner. By this modern method of

MAKING BEDS FOR THE YOUNG CATERPILLARS ON WHICH THEY GROW AND ARE FED

breeding, the Tyrolese are quickly winning their way to a position of considerable importance in the European silk market, using French science in building up an industry that now seems lost in France.

A well-organized body of progressive silk-farmers could by the same method rapidly raise India to her old position as a silk-producer. For they would have one of the cheapest supplies of labor in the world, and a climate in which four crops of silk could be obtained every year. The furnishing of a silk-farm is extremely simple and inexpensive, particularly in a hot climate where little or no artificial heat is ever needed. Some open sheds, in which are long, light frames for holding lightly woven mats of reed on which the caterpillars live, and some brushwood or Chinese mats for the spinning of the cocoons are practically all that is required, in addition to the mulberry plantations surrounding the sheds.

Nowadays, few silk-farmers reel their cocoons. These are usually collected and dealt with in factories. At least, this is done in Europe at the present day, and it is becoming somewhat of a general practice in China and Japan. Home-reeled silk, taken from the live cocoon, is more lustrous than factory-reeled thread, and this is why both the raw silk and the woven fabrics of China are more brilliant than the products of Europe. On the other hand, the system of factory reeling results in a more even and stronger thread. And as strength of thread is a vital necessity in weaving on power-looms, the brilliant luster preserved by the old-fashioned method is now generally sacrificed.

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THE SILKWORM'S WORK COMPLETED — COCOONS FROM WHICH RAW SILK IS OBTAINED

SILKWORMS AS WORKERS IN A FACTORY

FEEDING SILKWORMS WITH MULBERRY LEAVES

MAKING BEDS FOR SILKWORMS TO SPIN UPON

PICKING OUT THE FINISHED COCOONS

WEIGHING THE SELECTED COCOONS

By whatever method the cocoon is reeled, the task is quite easy. The silk ball is thrown into a tank of warm water to soften the silk-gum and set free the fiber. The loose outer case of floss silk is then removed, and the end of the thread forming the true cocoon is readily found. The thread is several hundreds of yards long, and it is this extraordinary length of unbroken fiber which distinguishes silk from cotton, linen, wool and other weaving materials. There is no need to card it and twist it; it needs only to be unreeled. Yet it is so fine that thirteen hundred yards weigh only the seventeenth part of an ounce. This extreme tenuity, however, is of no practical use. So the reeler usually takes six cocoons from the tank, and passes their threads over a rod, and through the eyelet holes of the machine, through which they run in a compound thread on to a revolving wheel.

THE STOVE FOR SUFFOCATING THE CHRYSALIDS

When reeled into skeins the material consists of raw silk. It is composed of two substances secreted by the silkworm — fibroin and serecin. Fibroin is a horny kind of substance that forms the core of the thread. It cannot be dissolved in water, even at boiling heat. The serecin can be so dissolved, for it is a kind of gum deposited on the surface of the thread. As produced by the silkworm, silk consists of two fine strands of fibroin, slightly twisted together and coated with the gum. The fiber is about the three-thousandth part of an inch in thickness, and of remarkable strength. A twisted thread of it, finer than the finest human hair, will stretch half a foot to the yard, and support a weight of about a pound. No other fabric material is so strong. Pure silk is both more beautiful and more durable than any vegetable fiber; and if it were not now so terribly adulterated it would often prove more economical in use than all fabrics of cheaper stuff.

The first step in the manufacture of silk is known as "throwing". The skeins are soaked for some hours in warm, soapy water, and then dried and stretched on a light skeleton reel called a "swift". Having found the end of the thread, the woman winder passes it through a guide wire and lightly attaches it to a revolving bobbin. As the bobbin revolves it draws the thread from the wheel, with so gentle a motion that if the threads stick through any reason the machinery stops. Thus the breaking of the thread is avoided, and hundreds of yards of continuous fiber are neatly wound on each bobbin. The thread is afterwards rewound over a double knife that cleans the silk of all unevennesses and hairy filaments.

The next process is sometimes called spinning, but the proper term is "throwing". For silk does not need to be spun, except when it consists of the little broken fibers obtained from the outer covering of the cocoon. It already consists of a long, continuous thread, and as soon as it is cleaned it can be woven into pongees. But to make stronger fabrics the single silk is twisted into a little compound thread on a throwing-frame. The action of the frame

depends on two sets of bobbins that revolve at different speeds, and, by the way in which their revolutions are adjusted to each other, more or less twist is given to the thread thrown. The two chief varieties of thrown silk are organzine and tram. To the organzine a great deal of twist is given, to make it hard and strong.

It is used for warps, which are the long, lengthways threads of a web that are tightly stretched in the loom before weaving begins. They bear the strain and the friction of weaving, and thus need to have great strength and evenness. Tram is less twisted than organzine, and therefore more soft and flossy. It is used for the weft or filling, the crosswise thread that knits the warp together into a web of fabric. There is little strain on the weft, but it must be soft and bulky, so that its successive threads may lie close together and fill up the interstices of the silk.

The eighteenth century, which was marked by so many epoch-making inventions for the improvement of textiles, including Kay's shuttle (1733), Strutt's ribbed stocking frame (1758), Hargreave's spinning jenny (1770), Arkwright's roller spinning (1771) and Crompton's mule (1776), changed spinning from a hand to a machine operation, and was the real beginning of the factory system, ushering in the revolution that followed the application of power to industry. Inasmuch as silk requires much more delicate handling than either cotton or wool, most of these inventions were in use in the cotton mills 20 years before they were successfully applied to silk. In 1801 Joseph Marie Jacquard of Lyons exhibited at the French Exposition his machine for weaving patterns, in which cards replaced the system of cords and complicated tie-up of the draw loom. Jacquard suffered from the usual hostility meted out to inventors, was burned in effigy and his machine smashed by the crowd, but today most figured designs are woven on a Jacquard loom.

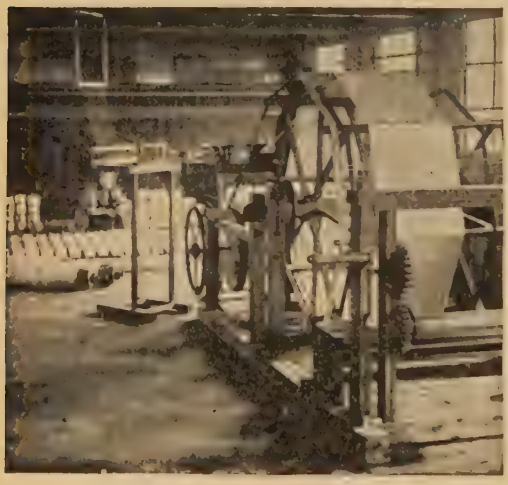
A JAPANESE WOMAN REELING THE SILK OFF A COCOON

VARIOUS PROCESSES OF SILK MANUFACTURE

REELING SILK FROM COCOONS IN HOT WATER

WINDING RAW SILK INTO SKEINS

HAND-TURNED MACHINERY FOR WINDING RAW SILK



WARPING SILK THREADS

WINDING SILK ON SHUTTLE BOBBINS

IN A LAND OF SILKWORMS AND CHEAP LABOR

PREPARATIONS FOR WEAVING

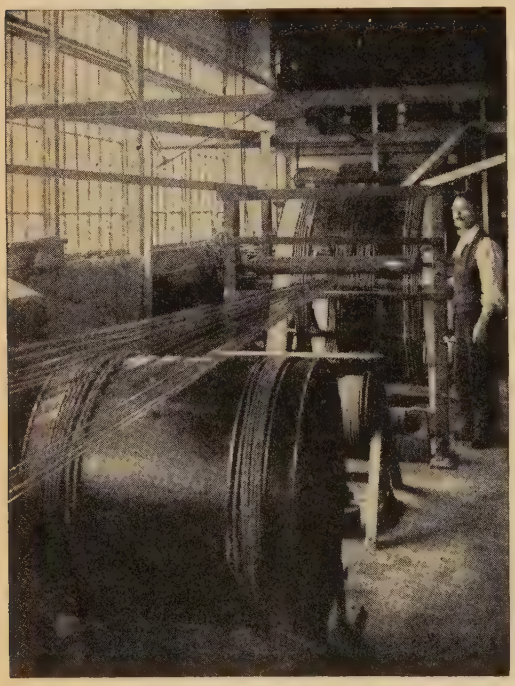
SILK-WEAVING AS A DOMESTIC INDUSTRY

GIRLS ATTENDING TO THE WEAVING OF THE SILKEN FABRIC

BOILING GUM OUT OF THE SILK

DYEING THE FINISHED PIECES

In making cheap silk, the thread is woven as soon as it is thrown—that is to say, the silk is not first boiled and dyed. Good silk goods, however, are woven from yarn-dyed thread. The skeins of silk are first boiled, in order to extract the gum and the color. Before being boiled, silk is harsh and wiry, resembling somewhat fine horsehair. It also differs in color, according to the place of its origin. Italian silk is yellow; Chinese and Japanese wild silk, light fawn in tint; while the best Chinese silk is nearly white. But the boiling extracts the color as well as the gum, and



SILK COMING FROM THE REEL AND SPREADING OUT ON THE WARP ROLL

leaves the thread of fibroin soft, white and brilliant. The weight of the material is also considerably lessened, sixteen ounces being reduced to twelve after being boiled for two hours in soapy water and then rinsed thoroughly to get rid of the gum and soap. Copper tanks, known as "barcs", are used in dyeing. The skeins of silk are hung on sticks that rest on the edges of the barc, leaving about three-quarters of the skein submerged in the bath of liquid dye. By turning the skein on the stick at regular intervals the dyer gets all the material equally colored.

The liquid in the barc is formed of the water in which the silk has been boiled, and with it is mixed the dye-stuff, which is either a natural product or an alizarine synthetic chemical, the ordinary aniline dyes being unworthy of being applied to good silk. Before being placed in the dye, the skeins are immersed in a solution of certain chemical salts, which prepares them for the action of the dyes. This process is called "mordanting"; and sometimes, when two skeins, that have been differently mordanted, are afterwards placed in the same dye they acquire entirely different colors. While the silk lies in the dye, steam is turned on, and the liquid is gradually brought to boiling-point. The dyer tests the coloring process by taking a skein off one of the sticks and drying a few of its threads. If the tint is right, the silk is rinsed very thoroughly. Then each skein is hung on a wall-peg and twisted by means of a stick, with all the force that the dyer can use. This is called "scrouping"; and though it may seem a severe process for so delicate a thread as silk, yet the fiber is so strong that the harsh wringing only enhances its

glossy luster. After the dyer has squeezed the silk nearly dry, the skeins are finished in a drying-room, and they are then rewound on bobbins ready for the weaver.

Unfortunately, both yarn and piece-silk are greatly adulterated at the present time. The boiling removes much of the natural gum, and lessens the weight by about one-quarter, and, to make up for this, unscrupulous dyers and manufacturers resort to "loading". Silk has a great affinity for water, and it can absorb one-third of its own weight without feeling wet to the touch. But the dyers soon found that it would absorb other things besides water, and especially solutions of salts of tin and iron. Indeed, silk will take up so much of these metals with the dye that twelve ounces of boiled fiber can be increased in weight to eighty ounces, and still look like very bright silk. Most people like silk bright and shiny. They are so accustomed to the adulterated material that they cannot recognize a piece of pure silk when they see it. As a matter of fact, pure silk has a subdued, pearly luster, whether it is merely boiled off and freed from the gum, or carefully dyed with pure color.

Very brilliant silk owes its brilliancy to the great amount of metal or vegetable matter with which it has been adulterated. Many silks in the market are now heavily loaded, and it is almost impossible to purchase pure silk goods that will stand the test of time and wear. The breaking-strength of a given unit of dry China raw silk is, say, 53. But some French silk, dyed blue-black and very heavily loaded, has a breaking-strength, for the same given unit, of $2\frac{1}{5}$. This, we will admit, is the worst case known to us; and an ordinary loaded silk may often be purchased with a breaking-strength of 10 or 12. But this is only about one-fifth of the original strength of the best natural silk.

Now, a silk can be made from wood-pulp with a strength of $21\frac{1}{2}$ when dry, and a little under $5\frac{1}{2}$ when wet. Thus, at its weakest, it is superior to a very heavily loaded natural silk in a wet condition.

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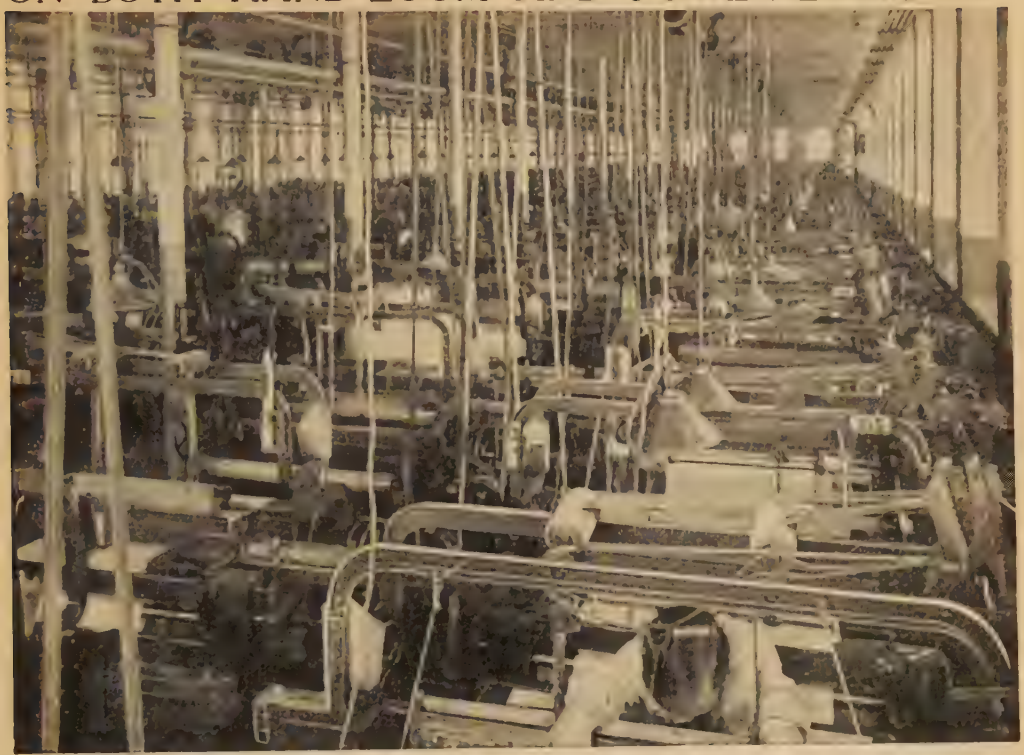
DRAWING MACHINES. CHENEY BROTHERS' FACTORY

THE SILK'S FINAL TRANSFORMATION SCENE

MAKING PLAIN SILK UPON A NARROW HAND-LOOM

PATTERNED VELVET FABRIC AS IT LEAVES THE LOOM

ON BOTH HAND LOOM AND POWER LOOM



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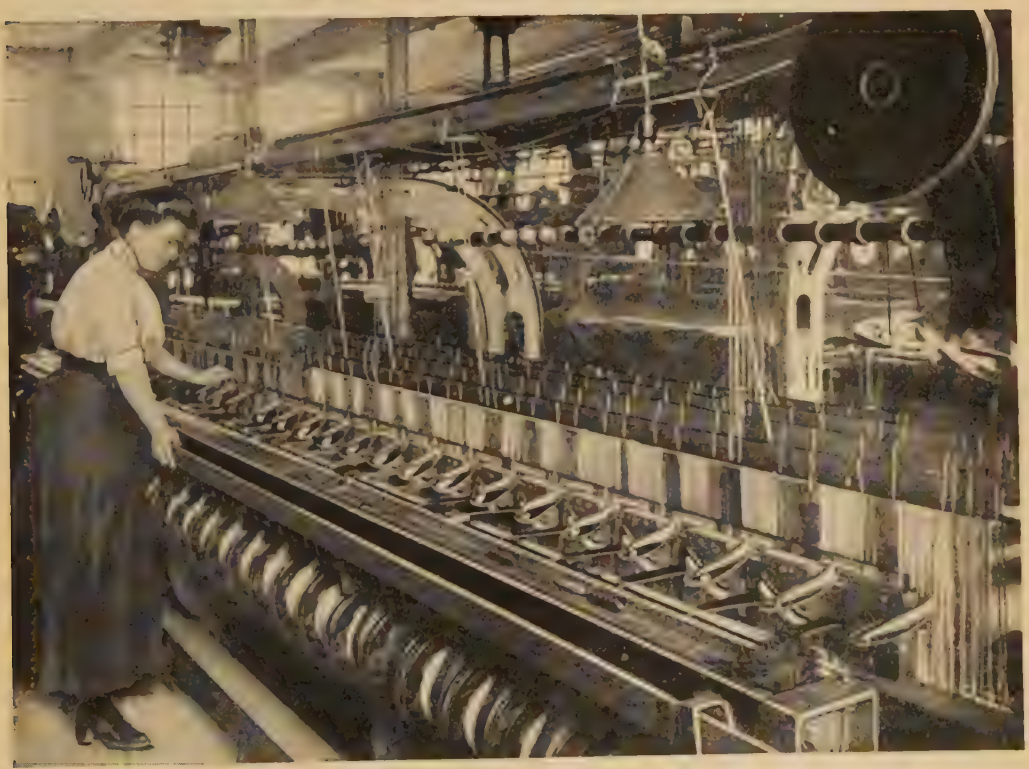
WEAVING ROOM, CHENEY BROTHERS' FACTORY



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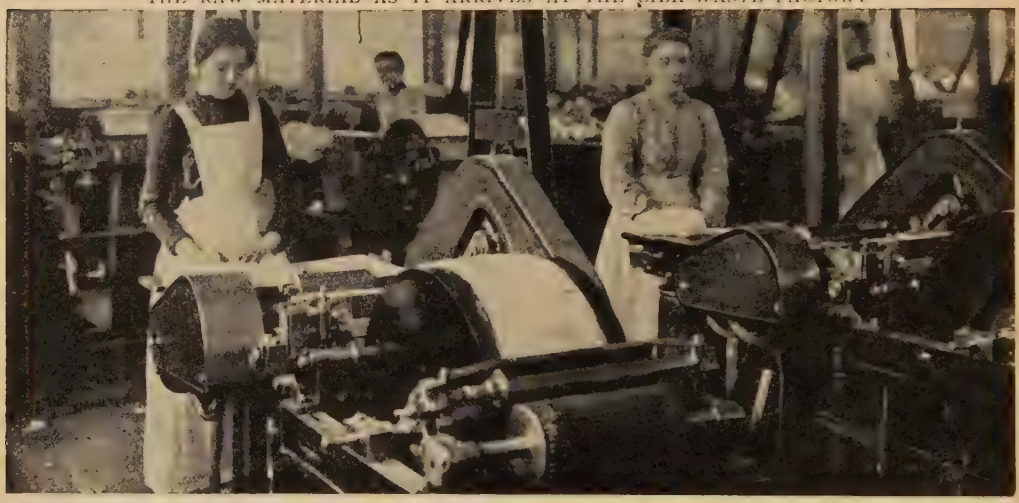
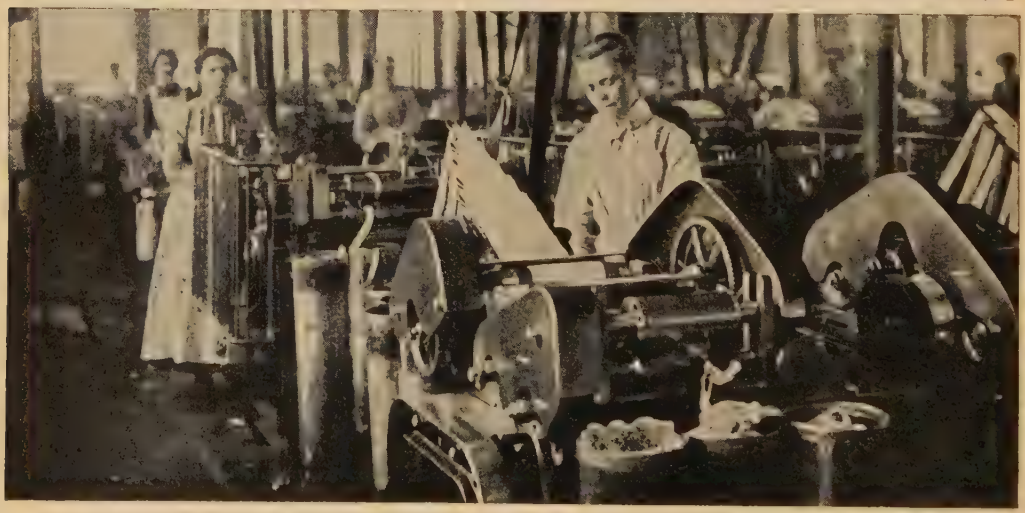
RIBBON LOOM WEAVING NECKTIES

MANUFACTURING SILK FROM SILK-WASTE

THE RAW MATERIAL AS IT ARRIVES AT THE SILK-WASTE FACTORY



THE PROCESS OF SPREADING THE SILK-WASTE AFTER IT HAS BEEN CLEANED AND DRESSED



DRAWING THE SLIVERS, PREPARATORY TO THE SPINNING OF SILK YARN

This is the reason of the sudden and extraordinary development of the new processes of making artificial silk. As we have seen, artificial silk becomes very weak when it is wet. The same thing happens to a less extent with boiled natural silk. It has a breaking-strength of, say, $25\frac{1}{2}$ when dry, and only of about $16\frac{1}{2}$ when wet. At present the best kind of artificial silk is almost as strong in its dry state as the best boiled-off natural silk, but when it is wet it is about $2\frac{1}{2}$ times weaker than wet natural silk. This disadvantage has not interfered with the large and still increasing use of artificial silk; and we are inclined to think that, if the loading of natural silk continues, the marvelous product of the silk-moth will be generally excelled by the creation of the chemist.

At present there are three processes of making artificial silk from wood-pulp or any other cheap source of cellulose. In the first process, covered by French and German patents, nitric acid is used. To prevent the nitrated thread from burning or exploding, like gun-cotton, the nitrate is afterwards removed, forming a product which is now an ordinary staple textile. In another German invention the wood-pulp is treated with a mixture of copper and ammonia. But the strongest artificial silk is made by the viscose process, which has already been referred to in the chapter on cellulose. In this the wood-pulp is first treated with a mixture of caustic soda and water, and when drained looks like bread crumbs. It is then put in a churn, and on it is poured a quantity of bisulphide. It turns yellow in the churn, and grows slightly warm, and water is then stirred into it and it is passed through a very fine filter. There are two ways of forming the liquid into a thread. In one it is sent through a number of fine glass tubes, and the separate threads are united in passing through a glass loop. In the second method it is sent through a nozzle of platinum, perforated with fourteen to eighteen holes. Each hole contributes a thread, and all these threads are drawn forward through a tank of liquid chemicals, which purifies the viscose. In the form of a compound thread, the strands ascend a glass roller and fall through a funnel into a spinning-box. By its motion the box draws the thread forward, and twists it, and lays it down in the shape of a hollow cocoon. In this form the artificial silk is taken at intervals from the spinning-box, and rewound into skeins, and further manipulated for the purification of the cellulose. Artificial silk thus prepared is much stronger than that obtained by the other processes, yet it is still inferior to unadulterated natural silk in its resistance to rain and moisture.

Although several attempts have been made to produce raw silk in the United States, none of them has been really successful, not because mulberry-trees and silk-worms cannot be raised in this country, but because silk cannot be grown by the highly paid labor of the United States in competition with Oriental and Italian drudgery. But the manufacture of silk goods, as with all other textiles, has been so revolutionized in recent years by the application of inventions and power, that the silk manufacturers of the United States, essentially the home of the machine, not only include some of the greatest concerns, but produce much of the best silk in the world. In Colonial days such silk as was made here was reeled by hand, thrown or twisted and doubled by hand, and woven on a crude foot-power loom at home by the women of the family.

The first silk-mill in the United States seems to have been started by Rodney and Horatio Hanks, at Mansfield, Connecticut, in 1810. The mill was but twelve feet square, and was intended to make sewing silk and twist on a machine of their own devising, run by water-power. In 1815, William H. Hortsmann built a mill in Philadelphia for trimmings and ribbons in which he attained partial success with machines for plaiting, braiding and fringe cutting. A Jacquard loom was imported by him in 1824. The first really permanently successful silk manufacturers in the United States were the Cheney Brothers of South Manchester, Connecticut. Their original mill was started in 1838.

IDEAL MEN OF OUR ANGLO SAXON RACE

KING ARTHUR, BY VISCHER — AT INNSBRUCK

ST. GEORGE, BY DONATELLO — AT FLORENCE

THE PEOPLE CALLED EUGENISTS

The New Science That Would Control
the Future and Create a Nobler Race

THE FORCES THAT MAKE MEN WHAT THEY ARE

THE people called eugenists believe that the soul of all improvement is the improvement of the soul; that, since individuals are mortal, the quality and quantity of parenthood are the dominant factors in the destiny of any people; that the culture of the racial life is the vital industry of mankind, everywhere and always; that every child who comes into the world should be planned, desired and loved in anticipation; that the function of government is the production and recognition of human worth, and the extirpation of human unworth; and that to these incomparable ends, for which the world was made, all powers of man and of nature, all forces, spiritual and material, must be made subservient.

These people number among them all the great thinkers and students of mankind, all who have perceived and striven, and whose spiritual heirs we are. Plato was a eugenist, no less than Francis Galton. The great poets are eugenists, one and all, as a volume might be occupied in proving. They have all known in their hearts what Whitman knew, when he said: "Produce great persons, the rest follows", and what Wordsworth knew, when he asked:

What one is, why may not millions be?
What laws are set by Nature in the way of such a hope?

Let us be assured that this is no new fad, but rather the modern form of the idea and the ideal to which the noblest men and women of the past have consecrated their powers.

Its modern characteristic is, as we find in every other sphere of thought and action, that it has become informed with science. The people called eugenists desire and hope for what all people worthy to be called human have desired and hoped for — the coming of nobler and finer men and women, the disappearance of disease and ugliness and misery and vice, the making of a better world, the dawn of the Golden Age which poets fabled in the past, but towards which we know our feet are pressing.

But eugenists say that if these ideals are to be achieved, more is needed than noble statement of them, more than prayers and tears and faith, more even than hope and courage. "To work is to pray", and the call today is for the faith which works. The task is our task, because we are also, in the great phrase, "partakers of the Divine nature", and are called upon to do our part in the task of creation. We generate the race, and we must regenerate it. The records of the past give us our warrant of possibility, if we consider whence we have sprung; they give us all-important guidance as to principles and methods; and while the past thus teaches us, it also inspires us with the idea of a mighty debt which we owe to the past, and can pay only to the future. "To the solid ground of Nature trusts the mind which builds for aye." If we are to build a fine race, which is greater than building cities, and is indeed the object of building noble cities, we must lay our foundations in this solid ground.

At this point eugenics, which was already seen to be a religion, is seen to be a science also. If we are to practice our religion, we must bring science to our aid, and we shall later discover, more clearly every year we live, that not one science nor two, but many, if not all, are called upon to contribute their share of guidance, warning and inspiration for the eugenist.

The need of translating the eugenist's accepted creed into deed

The time has come when these people are definitely called upon to state, not so much their creed, as their proposals for translating that creed into deed. The eugenic idea is accepted; the first articles of the creed have won assent, hearty or formal, active or passive, from all people. They are beyond challenge. If our campaign is to remain there, everyone may say that "We are all eugenists nowadays," just as Sir William Harcourt said: "We are all socialists nowadays." But socialists reply that, while this is in a sense true, they nevertheless are a distinct people, not because they have a distinct object — for we all want everybody to be happy — but because they have a distinct theory as to how that object may be attained. Just so, eugenists reply that, though all men desire what they desire, they are nevertheless a distinct people, not only because they keep that end more clearly and whole-heartedly before them than other people, which is certainly the case, but because they have a distinct theory as to how this desire of all men may be attained, a theory which is not the aristocrat's or the socialist's, but is original with the eugenist, and with him alone.

Nature and nurture, two factors in the development of every individual

Here, then, the writer sets forth the practical and immediate principles which must be admitted by eugenists. Though some of these principles may be more important than others, or more practicable or more urgent, none must be omitted, for all are essential.

It being granted that our object is the making of noble individuals, we have first of all to ask ourselves: What are the factors that make the individual noble or base, healthy or diseased, tall or short, clever or stupid, kind or cruel? The answer is clear. Every attribute and character of every living being is the product of what we may conveniently call "nature" and "nurture". These terms were adopted by Sir Francis Galton from a phrase of Shakespeare's, and they are so convenient and apt that they are rapidly coming into general use. The student knows that they are invaluable and indispensable at every stage of his study and interpretation; and they must be considered in detail later. Meanwhile, we recognize that "nature", including heredity as that is usually understood, and also everything else given at the individual's beginning, though it may be unlike anything possessed by the parents; and "nurture", including all nutrition from the moment of the formation of the new individual onwards, all environment, physical, social, spiritual — that these two cover between them, if they be properly understood, the whole of the forces that make us, or that make any living being, past, present or to come. And we recognize that both are essential, for if there be no nature, nurture is impotent; and if there be no nurture, nature comes to no thing.

The great end of eugenics is fine germ-cells for fine people

If this be granted, we have made a great stride. The eugenists, while proclaiming a new doctrine, must assert their assent to an old doctrine, and must admit it to be *no less essential* than their new contribution to the argument. They must admit the whole of nurture. It is not as if the end of eugenics were the production and mating of fine germ-cells. We want not germ-cells, but people; and we want germ-cells, however fine, only because they develop into people. We must therefore nourish them, at every stage from the first to the last. This establishes, for instance, the case for the care of expectant motherhood as essential to eugenics, though many professing eugenists protest at this

point, and call the care of a child before it is born "socialism", and look upon it as very nearly irreligious — though to pay later, in children's hospitals, for our neglect of the unborn appears to them charity, and therefore religious. This kind of folly has only to be exposed to be despised, and we need say no more of it in this place.

Are all men born free and equal into the world?

There is therefore a nurtural eugenics, an essential and integral part of our science and our practice. The asserted opposition between eugenics and social reform, eugenics and education, eugenics and philanthropy, does not exist. The eugenist accepts, welcomes, seeks to extend all the agencies that make for better nurture, alike for rich and poor, born and unborn. If and when he quarrels with those who are nowadays sometimes called the environmentalists, and thereby denies the value of environment for his own ideal, he is talking nonsense, and arousing opposition between those who should be friends and allies.

But the difference between the people called eugenists and other people lies in the fact that they recognize the factor of "nature", or heredity, *as well as*, not in place of, the factor of "nurture", or environment, in the making of human beings. If partisans, calling themselves eugenists, desire us to exchange the obvious half-truth called "nurture" for the obvious half-truth called "nature", we must not listen to them. But the eugenist is compelled to insist that his *special* contribution to the whole truth is necessary and essential, and that the whole truth cannot be seen without it.

The eugenist maintains that when we say "All men are born free and equal" we are stating a truth or an ideal which is political, not biological. The political truth is glorious and never to be decried; but neither must it be confounded with the biological truth, which is that, vitally speaking, not only are all men not born free and equal, but all men and women are different, and some are as certainly doomed by their nature to inferiority as others to superiority and freedom. If all children begin alike, and if the differences between men are therefore all due to nurture, then plainly what we here define as nurtural eugenics is the whole of eugenics. But if children differ inherently, and if these differences are not accidental, but proceed by law, and if they range from the criminal lunatic to the saintly genius, from the blight of disease to the radiance and wholeness of health, then plainly nurtural eugenics is only a stage of the whole making of a man or a woman, and not the first stage, but the second.

Now, this argument exactly agrees with the experience of the last seventy or eighty years, in which, to consider our own country, so much has been done for social reform. We have spoken, in the chapter on public health, of one among many great movements for improving the "nurture" of our people. Even more important has been the whole Child Welfare program which has been and still is striving to insure the health, education and moral training of every child, largely through the increasing hold of the public school over the child's life. On the whole, the record is not one of the ennoblement of life, or, if it be so, at any rate too much remains to be done. We have wrought enormous improvement in the conditions of life, in housing and drainage, in diet and water supply, and in what is called "education", but which should never be so called without quotation marks, to indicate that there is another and better use of the term.

After all we have done, primary matters of the law of life have been forgotten

All these and much more we have attended to, but the weightier matters, or the primary matters, of the law of life have been forgotten. We have cared for the feeble-minded girl when she got into trouble, and for her feeble-minded child, when *she* got into trouble; and we now have three generations sometimes living together in squalor, or cared for by the county; for we have actually devoted ourselves to "nurture" in such a fashion as to insure, guarantee and multiply the quantity of defective "nature" in each succeeding generation.

This, then, to take only one instance — an urgent and soon to be corrected instance, fortunately — is what the eugenist means when he declares that the factor of "nature" or heredity has been forgotten; and even that it would be and is quite possible to attend to nurture in such a way as rapidly to cause the degeneration and complete ruin of a race. For instance, we might and do take great care of defective children, and of the defective babies of defective mothers — as we certainly should, but we also neglect myriads of healthy babies and healthy mothers. It can be demonstrated that in many instances these huge national experiments — far worse than any that the anti-vivisector objects to — insure the survival of a much larger proportion of feeble-minded than of normal children. Plainly, our care must become more careful, our philanthropy more philanthropic; or in a few generations the end would be in sight.

Too frequently the eugenists attempt to buttress their case with illustrations which do not illustrate it. For instance, they argue that the race is degenerating because the birth-rate is falling more rapidly among the middle-class than among the artisan class. It may be so, but it requires proof; and there is very little evidence forthcoming — even though we wade through a wilderness of statistics, we find that the investigators one and all fail to consider the differences in nurture between these two classes. This kind of argument is worse than worthless for the eugenic case; but the wise eugenist will instance the feeble-minded, and will convince therewith and forthwith all but the very feeble in mind.

Should we not breed men as carefully as we do horses or roses?

Now, if "nature" be so important, if the degree of its importance becomes more evident and massive and minutely detailed with every year of investigation, and if the experience of all who breed cattle or roses or horses or peas proclaims the same truth, are we not bound, by the highest of moral sanctions, to apply our knowledge to the incomparable and superlative case of breeding men? To this question the eugenists return the answer that this is our duty; that, notwithstanding all difficulties of ignorance, prejudice, convention, legislation or public opinion, that duty must be done, and that the time to begin doing it is now. Slowly, but as surely as the very flux of time, man will conquer these difficulties; the fools and the cynics and the impotent, their laughter and sneers and yawns, will pass into the jaws of darkness already gaping for them, and it shall be seen that the forces which have erected man from the brute and the worm are not yet exhausted in him.

If we are to conquer, we must learn how. Both hands, both eyes, both halves of our brains, both halves of every truth are needed for our purpose. We must make a fresh start, and to our nurtural eugenics, which everyone is agreed upon, we must add a natural eugenics, which everyone shall yet be agreed upon. If present people will not, or cannot, see it, it will breed those who will and can!

Now, these two portions of eugenics, corresponding to the two stages in the history of any individual, the stage of providing the material, and the stage of developing it, must be put in due relation to one another; and plainly we must speak of natural or primary eugenics, and nurtural or secondary eugenics. These terms do not grade the importance of "nature" and "nurture"; that is a kind of folly practised by those who measure life on paper, with no idea of a living thing. If both are essential, there is no more to say.

But natural eugenics is to be called primary and nurtural eugenics secondary, because that is their order in time, that is their order in logic, and that, notwithstanding all our doings hitherto, must be their order in practice. For the first time in the history of modern civilization — Sparta and Israel were forerunners — we are about to begin at the beginning, which, for each of us, is our "nature", our parentage, through the germ-cells whereof we were compounded. This is not sufficient, but it is primary, and nurture, even including ante-natal nurture, is secondary; this we must do, and not leave the other undone.

What steps we are taking towards antenatal nurture

No more need be said at this point regarding nurtural or secondary eugenics. We shall see in due course that, though this is not the special contribution of the eugenists, they have their own view of it, and a very illuminating view it is. We shall see that, while others agree about the nurture of the adult, say as to housing, or the nurture of the adolescent and the school child, and while lately public opinion has discovered the infant, the eugenist alone has discovered the wonderful, familiar, hitherto forgotten truth that *every one of us is alive for nine months before we are born.* When people insist on nurture, as they always do in the company of the eugenist, he replies: "Very well; since to nurture you appeal, then to nurture you shall go. It means more than you bargain for. Every expectant mother in the land involves the nurture of the next generation. Is there one expectant mother in America who is ill nourished, unprized, dishonored, worried, overworked in factory or home? If so, be as good as your word; and if you believe in nurture for the next generation, begin its nurture now." This is one of the great issues of immediate progress and none of us will live to see the full accomplishment of it, though the various state laws for the insurance of mothers and expectant mothers in industry are surely a eginning. We stand aghast at the spectacle when we consider that every year 25,000 infants under one year of age die of preventable diseases, and 25,000 mothers from lack of care at childbirth. And though our country leads the world in national and individual wealth, it must see with shame six other countries surpass it in the showing of infant mortality rates, and sixteen others in maternal mortality. It was to ameliorate such conditions that the Sheppard-Towner Bill was presented to Congress, calling for the creation of a Federal Board of Maternity and Infancy. This body should operate through the already established Children's Bureau, through public health centers, consultation centers, state universities and through popular instruction regarding the care of expectant mothers, and of children at birth and immediately thereafter. The bill carried an appropriation of $1,480,000 to be paid the states to promote this work which safeguards the earliest environment of our future citizens. Here one only makes a preliminary note — that "nurture", like most words that mean anything, means more than meets the casual eye or ear.

How natural or primary eugenics must be negative as well as positive

But now as to natural or primary eugenics, as we have proposed to call it. This is the really new and peculiar contribution of the peculiar people called eugenists, and it demands our specially careful and emphatic statement here. The term "eugenics", or good breeding, was introduced by Sir Francis Galton in reference to the possibility of breeding, more largely than heretofore, from "able" stocks, whose members would presumably be of special value to the community. That would be a eugenic selection practised among mankind. But all selection must really involve rejection; to choose is also to refuse; and eugenics must include not only selection of the "able", or the worthy, but also rejection of the unworthy, like the feebleminded, as those who are to become the parents of the next generation. The original or Galtonian eugenics may therefore be called positive eugenics, and the converse may be called negative eugenics. These terms were approved and adopted by Galton, and have found general employment. Positive eugenics we shall define as the *encouragement of worthy parenthood*, and negative eugenics — that is to say, good breeding in a negative sense — we shall define as the *discouragement of unworthy parenthood.* These are perfectly clear principles. Their practice may and does involve difficulties; it may even be largely impracticable, but these are indisputable and cardinal lines of action.

To these two objects of natural or primary eugenics a third must be added. Unfortunately, eugenists have not yet realized its importance, and, indeed, it involves a number of new questions and

difficulties. The proposition here laid down is that, if there be any agencies or substances at work which are capable of converting worthy stocks and worthy parenthood into unworthy stocks and unworthy parenthood, it is the duty of the eugenist to combat those agents. Students of heredity are satisfied that if a man loses a limb, for instance, or suffers blindness or facial disfigurement from smallpox, his subsequent parenthood is not prejudiced. His children will not lack limbs, nor sight nor healthy skin. These are instances, which might be indefinitely multiplied, of parental damage or poisoning which does not affect offspring, and therefore scarcely concerns the eugenist. But the few who have paid special attention to this highly obscure department of heredity are aware that certain agents are as definitely capable of injuring parenthood, by their action on the parental tissues, and to these substances the writer has given the name of racial poisons. Most injure the individual, but they poison the race by direct action on the germ-cells, of which the individual is the trustee and the host, and therefore we shall sharply distinguish them from substances which injure the individual alone.

Preventive eugenics to combat racial diseases caused by racial poisons

That there are such agents is unquestioned, though there is need for further knowledge as to many which should probably be added to the list. What they are is not our concern here, though it may be briefly noted that the most important of them in this country are the obscure toxins produced by the parasites of certain diseases, and three well-defined and familiar substances — alcohol, lead and arsenic.

We are now in a position to complete our statement of natural or primary eugenics. We require not only to encourage worthy parenthood and to discourage unworthy parenthood, but also to combat the racial poisons, which are liable to turn worthy into unworthy parenthood. The writer has adopted the term preventive eugenics to indicate the prevention of the racial disease caused by these poisons.

With this the principles and the categories of the eugenist are completely stated, so far as present knowledge goes. One is compelled to recognize that more may yet be possible. It may be shown that certain agents, brought to bear upon the individual, directly improve his parenthood by changing for the better the germ-cells which he bears. At the present time science knows nothing of any such definite agent, and therefore what might be called a constructive eugenics must be left for the future, if possible, to practise. Meanwhile, the foregoing terms and definitions exhaust and comprehend the possibilities.

In tabular form we may set them down in this way.:

Natural or Primary Eugenics

1. Positive — encouraging worthy parenthood.
2. Negative — discouraging unworthy parenthood.
3. Preventive — opposing the racial poisons.

Nurtural or Secondary Eugenics

1. Physical — including nurture from the beginning — not merely from the cradle — to the grave.
2. Psychical — including education.
3. Social and Moral — home, school and nation.

Are we born or made? Human nature a union of nature and nurture

First, last and always, the eugenist must guard against a one-sided emphasis of either of the two great sources from which human character and characteristics are derived. Much, perhaps we may say most, of the serious discussion of the problem of man-making is vitiated by the almost exclusive adoption of one or the other of these two points of view. It is a matter of scientific interest and professional bias. When the biologist or man trained in biology discusses human nature we are likely to be given an absolutely fatalistic picture; all is given at the beginning; it is in the protoplasm, and nothing to be done about it unless we are to treat people after the fashion of live stock and breed for more desirable qualities. On the other hand, the educator seems commonly to assume that by training you can literally make a silk purse out of a sow's ear.

Both these positions of course are egregiously wrong. And it is hardly less wrong to treat human nature as the *sum* of the results of these two sets of influences, because such a view hopelessly confuses the problem and makes understanding impossible. It is quite absurd to divide a man, as it were, into two parts and say that "this" is due to heredity, while "that" is the result of environment. It is a different sort of a combination entirely. Every living thing is the *product* of the two *factors* of nature and nurture, not the sum of two parts. Alone, either of these is nothing. Heredity at most gives potentialities which must be developed by reaction with environment, and the potentialities are infinitely various according to the character of the environmental influences. Similarly, all that nurture or training can hope to do is relatively to develop or suppress what in germ is already there. When either factor is zero, the product will be zero, no matter what the size of the other factor.

Every human being is entitled to the best possible conditions of life

The position and scientific background of eugenists makes them especially liable to the biological bias and prone to underemphasize the importance of nurture and training. They must therefore be especially careful to give these their due, and to consider the whole of the factor of nurture. Only what is brought by the actual germ-cells, one from the father and one from the mother, which fuse to form the primitive cell from which every individual develops is really nature or heredity. Birth is after all only an abrupt and dramatic change of environment, and the influences that surround the developing body and soul in the long months of ante-natal life belong to the factor of nurture, or in the literal sense, education, just as much as what happens to the infant, child or youth.

It is eminently worth while to nurture well even those who may not have been well born. The rational eugenist can have no sympathy with those who discredit the science by advocating that infants not considered "fit" by some political board be allowed to perish, a practice harking back to barbarism. Besides the necessity of regarding human life as sacred if we are to preserve what is valuable in civilization itself, we must recognize the limitations of our knowledge. Newton, one of the greatest, if not the greatest, of modern minds, was a puny baby, prematurely born, and would undoubtedly have been selected for elimination by these self-styled improvers of the human breed. And Newton is only one example out of thousands. This principle must also be carried back into the period of ante-natal nurture. We must disown and discredit the lie that it makes no particular difference to the race whether expectant mothers and nursing mothers are given proper food and surroundings or are degraded by under-nutrition and by slaving in factories.

Environments also have children

Logically, it is true, nurture comes second in our study and in our campaign. But because this fact is even too well recognized and because the natural leaning of the movement is toward what we have called the "biological bias", it is well to insist first on the adequate recognition of the importance of nurture in all its phases. One especial reason for this is that the natural bias of the public is the other way, and we are dependent on public opinion for the practical realization of results. The demands of nurture are clear, requiring no previous research in genetics, and are already being applied in many ways, while our knowledge of heredity is very limited and the best counsels uncertain and often contradictory. We cannot too strongly condemn the preaching that heredity is all, or nearly all, when it is a matter of common knowledge that poison and disease are like the proverbial rain and sunshine in their lack of discrimination between the just and the unjust, between the fit and the unfit, and while large numbers of the community are subjected continuously to the action of all manner of poisonous influences, both before birth and after. The biological eugenist should hearken to the statement of Professor Pigou, that "environments also have children".

Great moral and psychological factors that must be considered

If it is absurd to pass over the factor of nurture in the formation of the physical and mental man, it is preposterous to neglect the decisiveness of the moral endowment, which is so largely a matter of the influence of environment. If we must distinguish between body and mind and recognize that the inheritance of ability and civic worth cannot be discussed in quite the same terms as that of eye color, we must still further differentiate between the determination of a man's conduct and that of his collar bone. We must reckon seriously with social psychology, the influence of imitation, suggestion and habit, with knowledge and all that goes to make up what Professor Baldwin well calls "social heredity". The events of these latter days should be enough to bring home to us the meaning and importance of *morale*, without which the best selected, trained and equipped army is chaff in a whirlwind. A society at peace has as great need for morale as has an army in battle. What a man believes may be as important as what he is, if, indeed, it is possible quite to separate the two things, and it is evidently unsuitable to compare a man's beliefs with his backbone when we are discussing nature and nurture. Obviously, nurtural eugenics, thus adequately conceived as the sum of all the influences which make, mold and modify man, must include many sciences which require separate treatment, *e.g.*, the science of health or hygiene, the science of social forces, and especially the great science of education. We cannot here take up the detailed study of these, but we can honor them for their services to the cause of human betterment and insist upon their study and application.

Educational limitations and fallacies. The necessity of a balanced view

On the other hand, we must also insist, this time more to the public than to the professed eugenist, on the limitations of nurture. Education is sharply limited by the nature of the material educated, and there is a sense in which this ultimate material is beyond its power to change. Before the modern study of heredity, such thinkers as Helvetius, Kant and Locke used to argue that the differences between men were all a matter of training, and likened the mind of a child to an unwritten page or *tabula rasa*, on which one might write anything at will. Now we know that the page of the youngest life is, as a modern student of education has admirably said, "so far from being blank that it bears upon it characters in comparison with which the faded ink of paleography is recent history". Education is, in fact, as much like the process of holding to the fire a paper already inscribed with sympathetic ink as it is of writing new characters upon the surface of a new mind. It is *both;* and this is the whole truth, of which we find it so difficult to appreciate both halves.

A second limitation of education is that its results probably cannot be transmitted to posterity. It must not be supposed that, if we educate the parents, the child will begin where they left off. Modern biology assures us more or less positively that it will begin just where they began. Our nature is our parents' nature and not their nurture; no literary training or achievements of theirs will make it one whit easier for us to learn our A, B, C's. What it can do, and all it can do, is to preserve and improve our environment or social inheritance. In this sense there is transmission of acquired characters, or progress would be impossible.

We must conclude this chapter by warning against some false conclusions which have been drawn from the eugenics propaganda, in many cases by persons bearing the name of eugenists and pretending to speak on its behalf. In particular, eugenics does not mean the application to man of Nietzsche's outrageous interpretation of Darwinism. It does not advocate any such measures as the "elimination" of the "unfit" by the deliberate neglect of child life, or the wholesale unsexing of responsible adults, the destruction of the family, and the "breeding up" of men by forced matings of the "fit" and the rearing of their offspring by wholesale methods.

TYPES OF A GREAT EUGENIC RACE — THE JEWS, WHO GUARD THEIR MOTHERS AND CHILDREN, and, amid extremest poverty, have the lowest infant mortality of all the races in the world.

Nor will eugenists allow the name of eugenics to be used as a cloak or pretext for economic and political reaction. It means not less but more attention on the part of society to the handicapped and endeavor to promote justice between man and man. We must repudiate in the strongest terms the position held in its barest and most stupid form by Herbert Spencer and his followers. It is incredible that intelligent men could imagine either that economic success proves social fitness and economic failure social unfitness, or that success and failure correspond in modern society with biological survival and extinction. Eugenists are therefore the friends, and not the foes, of public education, intelligent organized relief of destitution, and also of the social control of industry wherever it is in the interest of efficiency and justice. Finally, eugenists are not in favor of any social class to the detriment of any other class. They esteem merit, wherever found, and merit only, and the test by which they judge all human institutions is that of the quality of life they produce.

THE MARVELS OF THE SPIDER'S ANATOMY

MOUTH, WITH POISON FANGS

HEAD, SHOWING EIGHT EYES

FOOT, WITH COMB-LIKE CLAWS

A SPINNERET OF THE GARDEN SPIDER, SHOWING TUBES FOR THE DISCHARGE OF WEB LIQUID

ATTACHED ENDS OF A SPIDER'S THREADS

THE SPINNERETS OF A SPIDER

FROM WORMS TO INSECTS

The Bridging of the Wide Chasm
Between Bristles and Jointed Limbs

STRANGE CHAPTERS IN NATURAL HISTORY

IN an earlier chapter we traced some of the evolutionary changes in animal life which the observer may witness in progress, practically before his eyes. The present chapter demands that the mind take a leap across a vast span of life to view latter-day results of similar evolutionary changes. To do so we must disregard conventional classification; for while one aspect of our chapter faces the large sub-kingdom in which the worms, marine, terrestrial and parasitic, are grouped, the other is confronted by the highest type of backboneless animals. From Vermes to Arthropoda is a far leap today; but among the worms are descendants of the forms from which the vast assemblage of Arthropoda took their rise. Our survey suggests a fascinating train of improvement, achieved through long ages, with many a prolonged pause, with many a branching-off of new types, with many a regression and backsliding. We begin with forms like the worm in its burrow, or the loathsome parasite in the flesh of its living host; and at the other end of the scale we have the lobster in her sea-steeped cavern, intelligently sheltering her brood about her; the spider flinging her silken strands across unbridged chasms; the ant and the bee in their marvelous model cities.

This is indeed a most prodigious march, but we can trace the direction in which that march has been made. The model of forms, indeed, is broken, but we can still discover some likenesses between types of life now almost immeasurably separated. Among the worms are extremely primitive as well as degenerate types; among the Arthropoda are the most highly specialized of all invertebrates. The Arthropoda embrace five most interesting classes — the jointed-limbed animals; the Crustacea (crabs, lobsters, barnacles, etc.); the Arachnida (scorpions, spiders, mites and ticks); the Myriopoda (centipedes and millipedes), and, in the Insecta, all the host of insects.

Truly there seems at first sight little to associate the despised and lowly worms with masters of arts and crafts such as we find among the other great sub-kingdoms. Many important groups separate them; the Arthropoda, as a fact, constitute the second sub-kingdom of the animal world, while the worms form the seventh. But, far as the Arthropoda have traveled, they still, in important particulars, agree with such humble creatures as the bristle-worms, and certain of their allies. They are all, for example, divided into rings or segments, and their central nervous system consists of a ring round the front part of the digestive tube, thickened into a brain above, and continued behind into a ventral cord, which swells into a varying number of ganglia. Instead, however, of possessing paired, hollow foot-stumps at the sides of the segments, as is the case with certain of the worms, the Arthropoda are provided with pairs of solid-jointed limbs, of which at least one pair is modified into jaws. Cilia, which play an important part in the life of the adult or larval worm, are absent from the Arthropoda.

The briefest glance at the worms must suffice. Their classification is by no means a simple matter, for we have many associated forms, whether worms or Arthropods, whose features in common are rather more negative than positive in that they are to be identified, as in some cases, by the absence, rather than the presence, of certain characters by which the remainder may be recognized. The Archiannelida, minute and primitive marine worms, are to be noted as suggesting the characters of the ancient stock from which were derived the Annelids, a group in which, among other forms, we find the earthworms and leeches. The larvæ of one of the Archiannelida (*Polygordius*) assume a remarkable form, known as the "trochosphere", which ultimately becomes merely the head of the adult body, which latter develops as a narrow outgrowth at the rear, where it is divided into a number of segments. A similar larval peculiarity is associated with several of the next class, the Chætopoda, or many-bristled worms. These are a numerous assemblage of worms, marine, fresh-water and terrestrial, agreeing, for the most part, in the possession of bristles projecting from the sides of the segments, where, in many instances, foot-like processes, called "parapods", appear, and serve for the purposes of locomotion.

BRISTLE-WORM WITH ITS EGGS ATTACHED

CHÆTOPTERUS, PHOSPHORESCENT WORM

A well-known example is the sea-centipede (Nereis), known in our eastern states as the "clam-worm", a worm which may be seen crawling actively, at low tide, in search of living prey, which it seizes by means of powerful hooked jaws. An allied form, *Palolo viridis*, is eaten in great numbers, raw or baked, by Samoan, Fijian and other island natives. The so-called sea-mouse is merely a bristle-worm, and leads us on to the worms that dwell in tubes of their own making. A familiar example is the lugworm (*Arenicola piscatorum*), which fishermen probably regard as specially designed for use as bait. As a fact, it is one of the creators of a clean sea-shore. The lugworm eats sand for the sake of its organic contents, cleansing it and rendering it small and fine. Its work is compared to that of the earthworm, for it is computed that in the course of a year the lugworms of an average acre of sea-shore will produce in castings about 1900 tons, or a layer of thirteen inches.

Three notable forms of bristle-worms are Chætopterus, which lines its burrow with a parchment-like substance secreted from its own organs; Terebella, equipped about the head with tufts of filaments and cilia, which set up currents in the water bearing food to the worm; and Serpula, which fashions calcareous tubes on rock or stone or the empty shells of molluscs. Our next class, the Oligochæta, or few-bristled worms, are undoubtedly an offshoot of the foregoing group, but they have been vastly more important to the world. Here we find the earthworms, which Darwin, who devoted thirty years

THE SEA-MOUSE CLOTHED WITH IRIDESCENT HAIRS

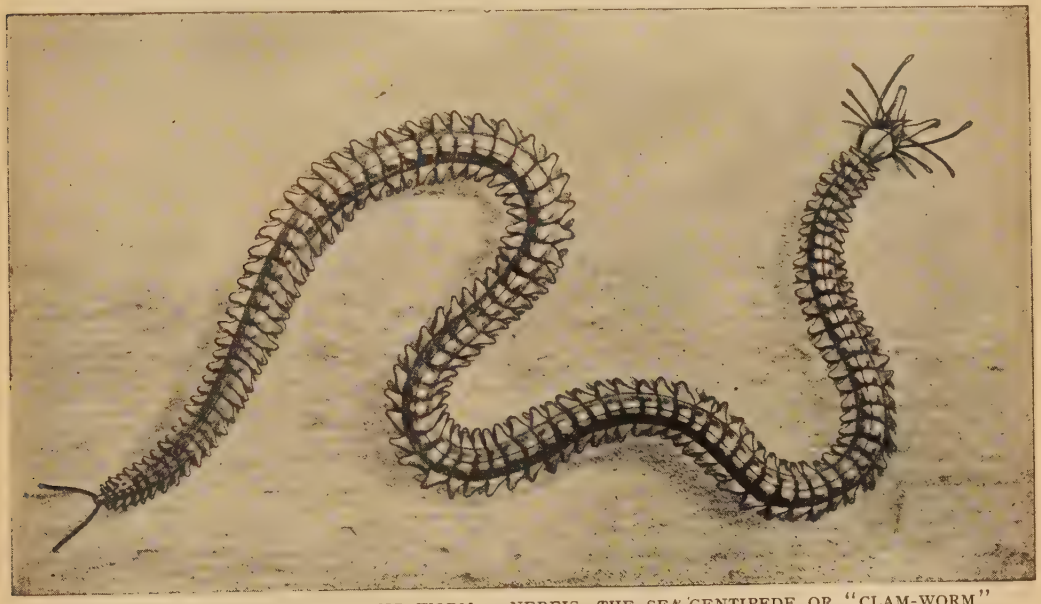
of intermittent study to the subject, considered the most important animals in the world in preparing the soil for man. Cowper little dreamed how well justified, on material grounds as well as humane, was his protest:

"I would not enter on my list of friends . . .
the man
Who needlessly sets foot upon a worm."

The worm is both earth-dweller and earth-eater. It tunnels in the soil and eats it for the organic substances contained. It draws into its burrow all manner of vegetable substances; and the leaves which we see standing upright, with their stalks embedded in the ground, upon our lawns — these leaves, tiny bits of twig and straw and hay, and so forth, have all been drawn into that position by the worms. Darwin calculated that in an average acre of garden soil there are about 53,000 worms, and that in the course of a year about ten tons of earth pass through their bodies. The result is that, in the course of fifteen years, in voiding the soil thus swallowed, the worms bring up earth from below representing a layer of three inches over the acre.

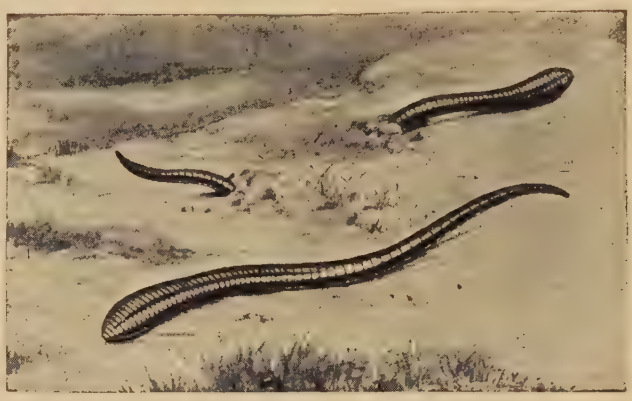
"Never grumble at the worm-casts", said a well-informed head gardener upon a large estate to his staff. "Take your broom and lightly distribute the casts over the lawn; it is the best soil in the garden, and the great natural lawn-improver." Worms are constantly at work aërating and draining the soil, reducing the loam to a fine state of division, and effecting that mixing which the farmer aims to do by plowing and harrowing.

Grant-Duff mentions in one of his diaries the fact that certain intelligent African tribes make their homes where they find earthworms plentiful, knowing that agriculture may be successfully practised only where these lowly creatures abound. The natives have a wider choice of these animated plows than is possible in the United States; for in Africa, as in the East Indies, earthworms attain a length of three feet and upwards, with a girth equal to that of a man's finger; while Australia has a related form (*Megascolex gippslandicus*) which measures six feet in length, and is said to make a "gurgling sound" as it retreats underground. We need not on this account accredit it with vocal organs, however, for the "gurgle" is probably akin to the curious sucking sound made by the withdrawal by a big tortoise of his head into his shell. It is the rapid expulsion of air from the burrow, not the voice of the worm that we hear.



AN ACTIVE CARNIVOROUS MARINE WORM — NEREIS, THE SEA-CENTIPEDE OR "CLAM-WORM"

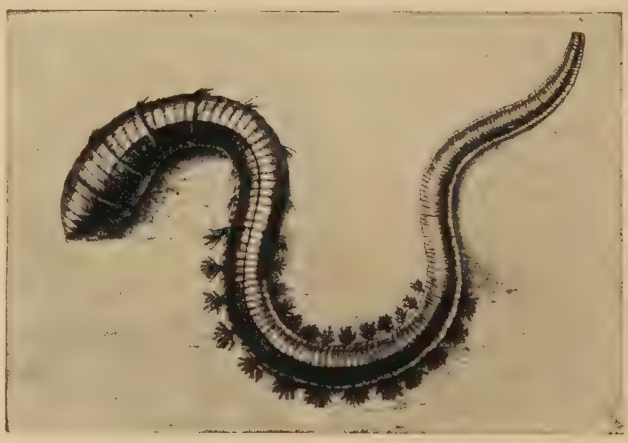
Like other forms of lowly life the earthworm can survive, under favorable conditions, the loss of part of its body. This is not surprising when we remember that a fresh-water member of the family, the beaked nais (*Nais proboscidea*), propagates by a process of transverse fission or division. The ordinary earthworms combine both sexes, but for the fertilization of their eggs they pair. These eggs are deposited in spindle-shaped cases or cocoons, formed by the hardening of a secretion from the parent worms. As mentioned, the earthworms are members of the few-bristled class. The bristles exist along the sides of the segments, and may be distinctly felt if a worm be drawn across the hand. It is these scale-like points which give the worm its purchase upon the ground, enabling it both to crawl and to retain its hold upon the interior of its burrow when an enemy seeks to draw it out.



THE FIRST PLOWS — EARTHWORMS

So far as we know, it has not been noted that the worm is able to concentrate enormous muscular effort into the resistance of a moment. A worm which you seek to draw from its burrow will oppose the first pull even to breaking point. But if it be held taut for a moment, then pulled a second time, it yields, almost without resistance, to the second tug. All its power of violent resistance seems to be exhausted by that first tremendous effort to withstand abduction. It will still cling, of course, as an entangled briar will, but the retractile energy appears to be dissipated by the initial effort at escape.

Following the few-bristled worms come the leeches, of which the medicinal leech (*Hirudo medicinalis*), once a famous ally of the doctor, is distinguished by the possession of three saw-edged jaws for piercing the flesh of a victim, and a duct from which is poured a fluid that keeps the blood from coagulating, and so makes a leech-wound difficult to stop bleeding. Among a great variety of other animals in this group we have the trichinosis worm; the threadworm (*Filaria sanguinis-hominis*), which gives rise in man to the disease elephantiasis; the parasitic round and threadworms which in various stages pass from invertebrate host to vertebrate, not seldom making man their medium. Then we have also the loathsome tapeworms, which have, as intermediate hosts, pigs, oxen, fresh-water fish, dogs and various other animals, and, finally, man himself.



A SEA-SHORE SCAVENGER — THE LUGWORM

The life-history of these disgusting parasites teaches one or two lessons: never to eat undercooked meat; nor salad unless it has been well washed; never to permit dogs to stray near vegetables from which salads will be made, and never to permit them to be near water which may be drunk by man;

never to permit a dog, whose tongue may carry the ova of these parasites, to lick our hands or faces, and, further, to keep our domestic pets free of fleas, which are often the first host of the ova of the tapeworm. The history of the parasitic worms is essentially unpleasant, and need not be more definitely traced; it is strange and terrible enough to justify the student's seeking it in its proper technical setting.

THE HORSE-LEECH, OR BLACK LEECH

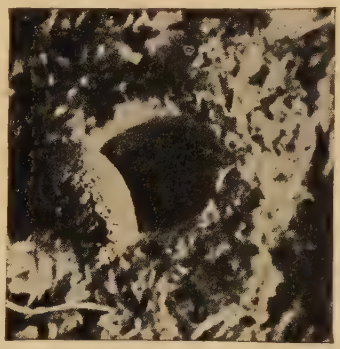
And now, having thus glanced at this lowly order of life, back to which we trace the rise of insect and related forms, we may pursue our way to the higher phases of life to which the collateral descendants of the ancestors of the worms have attained. We advance at a bound to the scorpions, for we have, in preceding chapters, passed in review the most remarkable marine forms of the Arthropoda, and in our study of the ants, wasps and bees have taken preliminary survey of the highest expression so far reached by this great sub-kingdom.

The scorpions, spiders, mites and ticks together constitute the Arachnida. Conversationally they are insects; scientifically they are not. In insects the head, thorax and abdomen are clearly separate divisions; in the arachnids the head and thorax are intimately united. The insect has six legs; the arachnid has eight. In some of the arachnids — the harvestmen, the mites and ticks — the cephalothorax, *i.e.*, the united head and thorax, is completely fused with the abdomen.

The first of the class are the scorpions, of which the warmer climates possess some two hundred species. Only the smaller kinds are known to Europe, the eight-inch examples being restricted to tropical lands. The large pincer-claws (pedipalps) serve for gripping prey; the small pair of pincers (cheliceræ), lying one on each side of the tiny mouth, serve further to grapple the victim nearer the mouth. The long tail contains at its extremity a sharp-pointed

A LINK WITH THE FAR PAST — THE SCORPION OF CENTRAL AFRICA

sting, which communicates with a poison gland. From this virus is ejected into the wound caused by the sting. Small animals, such as spiders, insects and lesser vertebrates, constitute the prey of the scorpion. Nourishment is assimilated by suction, so that only the juices of an animal can be taken. Perhaps it is needless at this late day to mention that the legend as to the menaced scorpion's stinging itself to death is false. Just as a snake cannot poison either itself or one of its own species, so the scorpion is immune to the effects of scorpion virus. Great antiquity is attributed to the scorpion, which is believed to have arisen from a marine stock, of which the still existing king-crab or horseshoe crab is thought to be the modern representative.

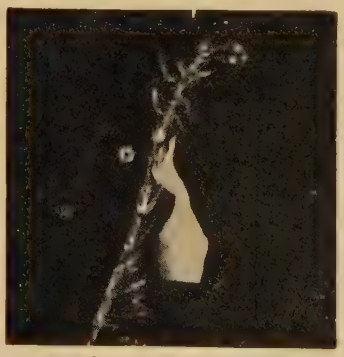


THE TRAP-DOOR NEST OF A BIRD-CATCHING SPIDER

The cousins of the scorpion, the spiders, are a numerous and specialized group, with a vast distributional range, and an infinite variety of devices in making a living. Needless to say, they are all carnivorous, and, that being so, they are, with few exceptions, entirely desirable members of the animal family. Apart from the wonders of their webs, spiders reveal amazing skill in some of their plans.

The engineering of the trap-door spider's home, for example, is a beautiful example of self-help. Compare that wonderful tiny dwelling with the abode of the cave-man. The entrance to the little home is the finest of all artificial portals not made by hands Beneath is a neat and well-designed burrow, luxuriously lined with silk, and closed against intrusion by a perfectly modeled door hinged with silk, and closed with the same material. The builder, not content with making all secure within, conceals the door of its dwelling by embodying in it fragments of moss or leaves or other vegetation, with the result that the whole exactly matches the surroundings. The scheme is deliberate, the resemblance of the trap-door to its environment is not accidental, for an investigator, having carefully excavated so as to carry away the top of the burrow with its door, returned a day or two later, to find a new door built, and its exterior crowned with earth and fragments of moss, which had been carried from a bank above. Some of these trap-door spiders are not comfortable with only one door between themselves and the world; they have two — one below the other.

A WATER-SPIDER BEARING AN AIR-BUBBLE TO ITS NEST AND CAPTURING ITS PREY



A SPIDER'S EGG COCOON HANGING FROM A STALK

Another species improves even on this, by making a second tunnel or tube, which branches off the primary one, half-way down, and ascends nearly to the surface, where it ends without exit. This would be useless without design behind it, and there is design. The opening between the two tubes is artfully closed by a trap-door, which is hidden behind the silken lining of the main tunnel. When its home is invaded, the spider pops behind the silken curtain, opens the door, passes through to the other side, closes that door after it and remains perfectly hidden. We may call that instinct if we like, but it is an instinct utterly eclipsing anything achieved by the highest vertebrates, man alone excepted. Think of the rough nest of broken twigs in a tree which so highly organized a creature as the orang-utang makes, and then picture the silken fortress of this little spider. The contrast makes the work of the spider inestimably admirable.

THE SPIDER, PHILODROMUS, IN ITS NEST ON A REED

But there is a still more challenging wonder in the work of the water-spider (*Argyroneta aquatica*). This is as completely terrestrial an animal, so far as physical organization is concerned, as the commonest of house-spiders. Yet this little aquatic animal makes a subaqueous balloon, rears its young within it and itself passes the winter within its shelter, under water. A beautiful contrivance is this little home of the water-spider, a dome-shaped bag of silk, woven beneath the water and attached to the stem of some plant, so that it is prevented from rising to the surface. The little balloon is inflated by the spider, which carries down a bubble of air at a time, such bubble clinging to the hairs growing upon its body. And in that magic abode this air-breathing animal dwells, when not out hunting, sustained by the oxygen he himself has carried down, an air-bead each journey. No fairy tale suggests a prettier idea. The water-spider anticipated the inventor of the diving-bell.

CONCENTRIC THREAD OF A GARDEN SPIDER SHOWING GLOBULES TO WHICH INSECTS ADHERE

THE WEB OF A GARDEN SPIDER

Then there is another water-haunting spider, the raft-spider (*Dolomedes fimbriatus*), of which examples are to be found in various parts of the world. This little genius constructs, and goes a-sailing on, a raft of tiny leaves, joined with infinite skill. From it she leaps every now and then, on to the surface of the waters, to catch an insect, treading the watery way with quite as much confidence as that merry water-treader the pond-skater.

Even these little beauties have a venomous sting. All spiders have; the tarantula worst of all. This much maligned

spider is simply a larger cousin of the big wolf-spider, and undoubtedly gives one a shrewd nip, which is followed by considerable pain, though not nearly so bad in effect as the sting of a scorpion. The tarantula has a shocking name. In the Middle Ages an epidemic suggesting St. Vitus' Dance spread over southern Europe, and, because it was attributed to the bite of this spider, it was named "tarantism". There has been a revival of it in Italy within the last few years, and distressing accounts were published not so very long ago. The disease really has no more to do with the tarantula than with the dodo, but is simply a nervous affection to which hysterical people are subject. In the old days music was declared to be the only cure, and a dance known as the "tarantella" is said to have originated from this treatment. Experiment has shown that the bite of the tarantula, though painful, and followed by local irritation, is neither fatal nor succeeded by any serious ill.

A FALSELY ACCUSED SPIDER — THE TARANTULA

The most loathsome of the spiders are the bird-eating examples (Aviculariidæ or Mygalidæ), happily restricted to tropical or sub-tropical climates. Little has been added to our knowledge of these animals since "Amazon" Bates wrote of them: "Many species of these monstrous hairy spiders, half a foot in expanse, which attract the attention so much in museums, are found in sandy places at Nazareth. The different kinds have most diversified habits. Some construct, among the tiles or thatch of houses, dens of closely woven web which, in texture, very much resemble fine muslin. These are often seen crawling over the walls of apartments. Others build similar nests in trees, and are known to attack birds. . . . At Cameta (equatorial Brazil) I chanced to verify a fact relating to their habits . . . worth recording. The species was *Mygale avicularia*, or one very closely allied to it. The individual was nearly two inches in length of body, but the legs expanded seven inches, and the entire body and legs were covered with coarse gray and reddish hairs. I was attracted by a movement of the great monster on a tree-trunk; it was close beneath a deep crevice in the tree, across which was stretched a dense white web. The lower part of the web was broken, and two small birds, finches, were entangled in the web. One of them was dead, and the other lay under the body of the spider, not quite dead, and was smeared with the filthy liquor or saliva exuded by the monster. I drove him away, but the second soon died."

The thickness of the Mygale's web is not without parallel. There are other tropical spiders which make webs stout enough to catch birds; and it is on record that one web contained a young mouse, which, ensnared as it ran along the ground, was girt about by separate threads of the spider and hauled four inches up into the web, where, after surviving for ten hours, it died. Snakes of small size, and a fish three inches in length, have been captured by the same means.

But for the wonders of web-making we need seek no farther than our own gardens,

where the garden-spider, malevolent queen that she is, devouring her lover with as little compunction as if he were a blue-bottle fly, is quite supreme in artistic and effective web-spinning. Fragile though her web appears, it is a structure of marvelous relative strength; and with all its foundation lines, on which the whole is hung, the radii that intersect the center, the inner spiral and the more elaborate and greater outer spiral, the whole dotted with some ninety thousand globules of viscid matter which imprison the lightest wing that touches it — with all this labor she begins and ends her task in forty-five minutes. That is, when she so wills. She may spin out the work over four or five hours, but the actual business of building takes no longer than three-fourths of an hour.

There is still much doubt as to the extent to which the spider relies on hearing and sight. Some writers believe that the hairs on the legs and palpi of the spider have an auditory function, and that the sight of the six or eight eyes is efficient. M. Auguste Forel believes that the spider sees little and hears less. That its tactile sense is highly developed there is not the slightest doubt. The slightest vibration of its web conveys a message, but that message is felt, not heard. The experiments with the tuning-fork, whose vibrations the spider has been supposed to hear, undoubtedly affect the spider only in so far as it feels the vibrations. The throbbing air actually strikes upon the entire body. So, when an insect enters the web, the spider probably feels rather

Pisaurus mirabilis *Atypus subseri* *Aranea adianta*

THREE INTERESTING TYPES OF SPIDERS

Where instinct begins and ends in this process we do not know. One thing certain is that the webs of the garden-spider are not always alike. Each web seems adapted to meet some special requirement, whether as regards climatic conditions, site, abundance or character of insects on the wing. Naturalists who have been making observations assert that they found webs differing slightly every day that the weather changed, as though the spiders had prepared in advance for the conditions to come. But unless one watched for twenty-four hours a day for a succession of days it would be impossible to say that the structure was not varied after the changes of the weather, not in anticipation of them.

than hears the disturbance created.

When a fly is enmeshed, the spider, warned by the vibrations of the web, leaps down her silken cable and, if she be not hungry, envelops the hapless victim in a sort of cocoon, and hangs it up, buzzing dolorously, looking like a tiny ham on a farmhouse ceiling. But when the more active struggles of a wasp set the net trembling, the spider, without going close enough to investigate, spins a long line round and round and round the prisoner, securely binding it before she approaches. And one has noticed that when a powerful insect is caught, and the web is threatened, the spider will seize a strand which appears likely to be torn from its anchorage, and pull on it with all her strength.

M. Forel adduces several points of evidence to prove that the spider does not see distinctly, but none more notable, perhaps, than an experience on record of an observer with a number of spiders in a large "live box". The results were certainly instructive so far as the spider as a diurnal animal is concerned. Seeing that it is day-flying insects upon which the spider has in the main to rely, this is a pretty good test, although she does build at night. In this box were flies as well as spiders, and the flies flew and leaped upon the spiders without let up or hindrance. It was only at night, as a rule, that the spiders ate their prey. By day they apparently did not see them — though, when a web was spun in the box, the usual course was followed. At night they probably found them either by accident or by scent — a sense, by the way, as to whose existence in the spider M. Forel is skeptical.

THE SCARLET MITE

But the strongest evidence as to the weakness of vision in the spider came from the actual meeting of spider with spider. Again and again two spiders, advancing by different routes, would blunder, head-on, into one another, and collide as helplessly as bats in sunlight. The moment they did so, without any attempt at recognition, such as ants would make, both would leap back in great agitation, and crouch an inch apart, "feigning death".

We have not yet solved all the spider problems. It must suffice for us that the family is one of the most remarkable in existence, and, for all its repulsive features, it must be awarded one of the first places in esteem for the marvel of its home-making, in water, in air, in human habitations, in the desert and in the tangled forest. We must not forget that, though the spider is a terrestrial animal, it is also a great traveler in early life. Probably it was the first of aëronauts flying by artificial means. Every summer millions of little spiders, known as the ballooning spiders, seeking new homes beyond the reach of their cannibalistic kin, set sail for a great adventure. Throwing out a web of the utmost fineness, to be caught by the wind, they tightly draw up their legs and, clutching their gossamer parachute away they go, borne by the breeze, sailing wheresoever the wind carries them.

We pass over the false scorpions, false spiders and the harvestmen — the spider-like creatures with tiny bodies and legs of inordinate length familiarly known as "daddy-long-legs",—to reach the mites and ticks. These are a multitudinous group, many of them parasitic, and producing great discomfort and bodily ill to their human and animal hosts. Others, such as the red mite, which plays havoc with hops and indoor growths such as the forced strawberry, causing in the latter that faded

A TROPICAL CENTIPEDE REPRODUCED IN ITS ACTUAL SIZE

spotted appearance of the foliage which they have drained of sap, are among the most familiar. Another species of red mite, *Dermanyssus avium*, infests poultry and neglected caged birds. The worm-like mites include the gall-mites, which do serious injury to such fruits as the black currant. The ticks, although in their early stages they are found upon plants, are parasites of animals. They include a parasite which affects sheep, others which attack birds and reptiles, while another family produces mange and itch. Eight species of ticks in the United States have been found upon cattle, the most noted being the one associated with the Texas cattle fever, particularly destructive to northern cattle shipped South or brought into contact with Southern infested cattle shipped north. In other countries there are other species which transmit similar diseases. Dipping cattle in cotton-seed-oil or one of several patent mixtures called "cattle dips" destroys the ticks.

Our chapter closes with the Myriapoda, a class comprising the centipedes and millipedes. Extinct forms show that they spring from a common stock, resembling the primitive and sluggish Peripatus, a deeply interesting living relic. The centipedes of this country are carnivorous, but are small and harmless to man. It is to the Geophilida that the well-known luminous centipede belongs. Many of the tropical species are possessed of a serious stinging weapon, the effects of which are severe. The least-specialized centipedes are the Sympala, of which one genus, the Scolopendrella, in spite of their wide distribution in America, Europe and Asia, preserve for us the likeness, little altered, of the lowly stock from which they originated.

PERIPATUS, THE SOLE SURVIVOR OF A PRIMITIVE CLASS

FOES TO AGRICULTURE — COMMON MILLIPEDES

The millipedes are all vegetable feeders, and some of them do considerable damage to the roots of crops, so that they are called false wire-worms, the latter being the larval form of true beetles.

COLLECTING MATERIALS FOR SCIENCE

Father's Mother

1. Full maiden name..... 2. Date of birth.....

3. Birthplace: Town.....County or Country.....

4. Residences, principal .....

5. Occupations at successive ages.....

6. [1]Lesser diseases to which there was any special liability — In youth ..... In middle age ..... In advanced age .....

[1]Serious illnesses, accidents and operations — In youth ..... In middle age ..... In advanced age .....

7. If dead, cause of death and age at death.....

8. Date of marriage..... No. of [2]sons { born ..... reaching maturity ..... No. of [2]daughters { born ..... reaching maturity .....

9. Presence of any special taste, defect, gift or peculiarity of mind or body.

.....

Important

(1) The Presence of Consumption, Rheumatism, Gout, Diabetes, Cancer, Heart or Kidney Disease, Epilepsy, Paralysis, Apoplexy, Insanity, Neurasthenia, Hysteria, Alcoholism, Mental or Nervous breakdown should be particularly noted.
(2) It is very desirable that miscarriages and still-births should be included in the total of children born; but children resulting from a previous or subsequent marriage should not here be included.
(3) If details are known concerning brothers and sisters of grandparents or parents, or half-brothers and sisters of informant, they should be recorded on a blank sheet or a separate form.
(4) In the case of Female children being married, the husband's surname should be added (in brackets).
(5) In giving particulars of children (pages 5 to 9) it is very desirable that *every* pregnancy, whether miscarriage, still-birth or full-time, should be included in its proper order.

	Father's Father	Father's Mother
SEX OF CHILD. F. Female. M. Male		
Age for which description is given		
10. Adult or present height, inches (no shoes) or *v. s.* (very short), *s.* (short), *m.* (medium) *t.* (tall), *v. t.* (very tall)		
11. Adult or present weight, lbs. or *s.* (slender), *m.* (medium), *c.* (corpulent)		
12. Colour of hair (before graying) *a.* (albino, white), *f.* (flaxen), *y-br.* (yellow-brown), *l-br.* (light brown), *m br.* (medium brown), *d br.* (dark brown), *n.* (black, *nigrum*), *cl r* (clear red), *d r* (dark red), *d b r.* (dark brown red), *s r.* (sandy red).		
13. Colour of eyes *p bl.* (pale blue), *d bl.* (dark blue), *bl br* (blue with brown spots), *l br.* (light brown), *d br.* (dark brown), *n.* (black), *y bl.* (yellow blue-grey or green), *r br* (reddish brown).		
13a. Note if colour differs in the two eyes, *dif.* or if eyes constantly wander or twitch, *tw*		
14. Complexion or skin colour *bl.* (blond), *i.* (intermediate), *br.* (brunette), *d br.* (dark brown), *n.* (black, *negro*), *y.* (yellow), *y br.* (yellow-brown), *r br.* (reddish-brown).		
15. General Mental ability *1.* (poor; failure to advance at school Age and class or standard), *2* (medium to good) *3.* (exceptionally good).		
16. Special ability in scientific research: Note—In each ability the grades to be as follows *1.* (poor), *2.* (medium to good), *3* (exceptionally good)		
17. Ditto in organisation or administration		
18. Ditto in music *m*, drawing *d*, painting *p*; sculpture *s.*		
19. Ditto in literary composition *l*, oratory *o.*		
20. Ditto in mechanical skill		

21. Ditto in calculating		
22. Ditto in remembering		
23. General bodily energy *1.* (very inactive), *2* (ordinary), *3.* (exceptionally energetic).		
24. Condition of sight *1.* (blind), *2.* (imperfect, wears glasses), 3 (ordinary), *4* (strong).		
25. Age when sight defect, if any, developed or, *c.*, (congenital, born defective)		
26. Colour-blind? State variety		
27. Condition of hearing *1.* (deaf), *2.* (defective), *3.* (ordinary), *4.* (strong)		
28. Age when hearing defect, if any, developed or *c.* (congenital, born defective)		
29. Condition or speech *n.* (normal), *l.* (lisping), *s.* (stammering), *d.* (dumb, speech unintelligible)		
30. Age when speech defect developed or *c.* (congenital).		
31. Temperament *p.* (phlegmatic, slow), *m.* (melancholic, pessimistic), *s.* (sanguine, optimistic), *c.* (choleric, passionate), *e* (excitable, emotional), *n.* (nervous, quick).		
32. Use of hands *a.* (ambidextrous), *l* (left-handed), *r.* (right-handed).		
Defects of bodily form as below Mark (X) any that may be present		
33. Birthmarks		
34. Hare lip *h l.*, Cleft palate *c p.*		
35. Abnormal fingers or toes		
36. Asymmetry of trunk		
37. Other traits not included above Their nature should be specified.		

FACSIMILE REPRODUCTIONS FROM THE TWELVE-PAGE PAMPHLET ISSUED BY THE EUGENICS EDUCATION SOCIETY TO GATHER PARTICULARS OF FAMILY RECORDS OF THREE GENERATIONS

MORE KNOWLEDGE WANTED

The Two Lines of Investigation into Human Heredity, Biometry and Mendelism

STEPS PROPOSED OR ALREADY TAKEN

IT has often been pointed out that it is absurd for man to take such pains as he does with the selection and improvement of the plants and animals he uses for burden-bearing, for food and even for pets or ornament and all the while to allow the human strain itself to propagate at random with no attention as to whether it is improving or deteriorating. It *is* absurd and, in view of the fatal consequences of a debasement in the quality of men, it is tragic as well. At the same time, our very achievements in the fields where a little care has been exercised, the marvelous transformations of domestic animals, pets, cultivated plants and flowers so that it is often impossible to trace their kinship with the wild forms from which they must have sprung, *seem* to prove what might be done in the way of improving the qualities of our own species, if we only would. And yet, — we don't ! How are we to explain this incredible inaction in regard to a matter in which all that men have ever counted good is at stake, and which seems so easily within our control ?

There has never been a dearth of people ready to answer this question with the confident assertion that it is all due to stupidity, inertia, "squeamishness" or what-not, that there is no real reason. But this line of argument is generally too easy. Something very relevant is likely to be overlooked in so obvious a conclusion running counter to all human experience. Unforeseen difficulties usually appear and multiply. So in this case; on examination the problem turns out to be not so simple as it looks. And even the "Utopian" Mr. Wells, who is willing enough to undertake the reconstruction of society in other respects (not so simple and obvious), frankly throws up the sponge in the face of this problem. He says: "The first difficulty . . . is that we are, as a matter of fact, not a bit clear what points to breed for and what points to breed out. The analogy with the breeder of cattle is a very misleading one. He has a very simple ideal, to which he directs the entire pairing of his stock. He breeds for beef, he breeds for calves and milk, he breeds for a homogeneous docile herd. Towards that ideal he goes simply and directly, slaughtering and sparing, regardless entirely of any divergent variation that may arise beneath his control. A young calf with an incipient sense of humour, with a bright and inquiring disposition, with a gift for athleticism or a quaintly marked hide, has no sort of chance with him at all on that account. He can throw these proffered gifts of nature aside without hesitation. And this is just what our theoretical breeders of humanity cannot venture to do. They do not want a homogeneous race in the future at all. They want a rich interplay of free, strong, and varied personalities, and that alters the nature of the problem absolutely." He then goes on to show that most of the supposedly "desirable" qualities in human beings, health, beauty, ability, energy, sanity and even immunity from diseases, are not at all simple things and that we do not know or cannot identify the elements of which they are made up nor predict the results of various combinations.

All this, even supposing that the reformer had the power over his human stock that the breeder has over his and that our moral sentiments, social conventions and individual wills were all out of the road. Mr. Wells concludes that, if the world were to accept the arguments of the propagandist improvers of the human breed and place itself absolutely in their power, "after a very brief epoch of fluctuating legislation, this committee, except for an extremely short list of absolute prohibitions, would decide to leave matters almost exactly as they are now; it would restore love and private preference, at the utmost it would offer some greatly qualified advice, and, so released, it would turn its attention to those flaws and gaps in our knowledge that at present render these regulations no more than a theory and a dream." Everyone admits the desirability of such action, but that we simply do not know how to do it; the dangers of doing much damage by taking a wrong course are about as great as the prospects of benefit from a right one, so that the results to be anticipated do not offset the difficulties of the attempt.

The beginnings of a science of human qualities. Francis Galton and eugenics

It is only very recently that any progress has been made toward transforming the hope of improving the quality of the human stock into more than "a theory and a dream". It is evident to the thoughtful that any real advance in this line must be based on more and better knowledge than untutored common-sense and unverified observation and speculation can give. As in so many fields, practical advance waits on scientific progress. Serious interest in the subject therefore is, and for a long time to come must be, limited to the accumulation of data on which intelligent action can be based, and our discussion should relate chiefly to the scientific side of the movement. Such positive measures as have been adopted or are reasonably advocated can then be briefly taken up.

The founder of the modern movement for the betterment of mankind by improving its natural endowments was Francis Galton, who also gave it the name of eugenics. Galton, who was an able biologist and a cousin of Darwin, became seriously interested in this field through the study of the latter's theory of natural selection. Just ten years after the publication of the "Origin of Species" Galton published his great work on "Hereditary Genius". It is essentially a study of the kinship groups to be found among men whose work had attracted enough notice to cause their names to appear in reference works on biography. The large number of instances of blood relationship among "noted" men and particularly the appearance of such men in successive generations of the same family, constituted, in his mind, a strong argument that "ability" is inherited. Galton later modified his views somewhat, and recognized that "eminence" is a very crude test of ability. He also substituted "civic worth" for "ability" as his designation for the general quality which society should seek to encourage, but it is hard to see how this is much of an improvement. If it is nearer to "fact", it is also much more vague and still quite unsusceptible of scientific identification and measurement. At first Galton had no special name for his new science; then he called it "viriculture", or culture of men; later this was changed to "stirpiculture" or culture of strains or stocks. It was in 1883 that he gave it the name of "eugenics", meaning good birth.

Galton's investigations into the laws of inheritance

From the demonstration that human qualities are hereditary, Galton proceeded to inquire into the manner or *law* of their transmission. To get any results in this field it was necessary to devise ways of measuring phenomena and accurately describing the distribution of cases in groups, and Galton's statistical or methodological work in this connection is probably of more scientific value than his primary conclusions. Measurements of simple qualities like stature showed that variations are distributed approximately along a "curve of errors" or according to the law of pure chance. That is, the various heights center around a "mode" which is the most

frequent height, and the number greater or less than this by any given amount falls away uniformly on both sides. Thus in the measurement of the heights of 8586 men, it has been found that over 1300 fell between 67 and 68 inches, while for one inch above or below this height there was a somewhat smaller number, approximately equal in the two cases, and so on. The number of men taller than the "mode" by any number of inches is as a rule about the same as the number who are shorter by the same amount. Galton also devised simple ways of describing the distribution of the instances about the typical value.

He then studied the question of the inheritance of qualities, and formulated the "law of filial regression", *i.e.*, if the parents diverge by a given amount from the most frequent degree of the quality, their children will also diverge but by a less amount, in the case of stature about two-thirds as much as the parents on the average of a large group. He also studied inheritance in successive generations and reached the conclusion that any individual gets about half his traits from his parents, one-fourth from his grandparents and so on.

Galton's theory of race-betterment and his practical program

Galton's theory of variation and inheritance was exclusively a statistical law of averages. He believed that in dealing with a large number of families successive generations would necessarily show the same sort of distribution among various degrees of any quality. How then could progressive improvement be secured? The argument was that if succeeding generations came predominantly from parents possessing the quality in a high degree, the center of the distribution or typical value (what we have called the "mode", because it is the term in use today, but which he called the "mid-parent") would be moved upward and the whole range of variation along with it. His ideas underwent some change but the essential thing in his mind was always to cause the number of people of high abilities or "worth" to multiply faster than those of low abilities or worth.

To secure this result, Galton emphasized early marriage. Comparing the rate of increase in a strain which marries generation after generation at 22 with that of a strain which marries at 33, he found that, at the end of a century, if they started with equal numbers, the first would outnumber the second 10 to 7, and at the end of two centuries 6 to 1. In order to encourage the early marriage of the "worthy", Galton made a number of concrete suggestions. He thought people might be graded on a sort of "point" system for all sorts of desirable qualities and those above a certain standard of "fitness" given a eugenics certificate or diploma. This should make them more desirable mates and they would be more eagerly sought and earlier married. He also favored endowments to people with high qualities so as to enable them to marry and, when married, to assist them in rearing children. One form of aid he suggested was that of cheap house rent. All this sounds rather far-fetched as a measure of practical politics, and it should be added that recent study of inheritance has raised grave doubts about the theoretical validity of raising the standard or norm of variation continuously by selection. It seems that all that can be done is to separate out the "pure lines" having the quality in question in the highest degree and that then improvement stops unless a "mutation" or in everyday terms a "sport" occurs. So far we have no knowledge whatever of the means of controlling or predicting mutations; they seem to be utterly freakish in character and manner of occurrence, relatively rare and of course much more liable to be undesirable than desirable.

Galton's successors. Karl Pearson and the biometric school

For many years Galton's propaganda was little more than a voice crying in the wilderness. Very little attention was paid to it outside of a limited amount of empty talk, pro and con, by a few men of science and the merely curious. The only notable exception to this attitude is that of Karl Pearson, the well-known statistician, who

early took an active interest in the question, both as a scientific problem and as a practical proposition. In 1904, however, came a change. In that year Galton, in an address before the English Sociological Society, aroused a keen interest in the subject of eugenics, and about the same time founded the eugenics laboratory at the University of London, with Pearson in charge. The journal *Biometrika* had already been started in 1901. Pearson and his associates have ably continued and developed the work of Galton, both in improving statistical technique and in the attempt to reach results of practical value. Their work has continued to be along the line of a mathematical study of averages and distributions in large groups, the idea being to establish statistical laws of inheritance. Physical traits have been studied by direct measurement and mental traits through questionnaires filled out by teachers in regard to school children and also through family histories. The publications of the laboratory constitute the most comprehensive studies and the largest collection of data which we have on the subject of eugenics and problems of heredity bearing upon it.

It is too early to gage the results of this work, which is still young and going rapidly forward. To date, about all that has really been done is to accumulate evidence that human traits run in families, of which we may fairly say that "everybody already knew that". It cannot be said to constitute that scientific basis for positive upbuilding of human ability and character by biological methods for which the world is waiting. Some approach has been made toward establishing "laws" of inheritance in terms of averages or probabilities — the most that the method is inherently capable of doing — but these are not of a character to afford a basis for action, even if other difficulties were removed. More definite criticisms of the work of the school are that the writers have made little effort to separate the effects of heredity from those of environment and have often treated statistical data rather uncritically. Clearly it will not do to assume that every trait manifested by children in common with their parents is inherited, else we should have to treat such things as good grammar as hereditary. In fact, it is enormously hard to distinguish innate ability from acquired information and skill, even under experimental conditions in a testing laboratory and with trained and capable investigators in control. Under the second point we will only refer here to the unwarranted confidence placed in the data from questionnaires on mental ability and traits furnished by teachers. Such data may have some value, but to put them through the mill of refined mathematical manipulation and deduce precise quantitative results is scarcely permissible. In short, while much valuable scientific work is being done, we are still remote from the knowledge which will form a confident connection between a program of action and desirable results.

New lines of attack. The Mendelian theory of inheritance

It is evident that the Galtonian or biometric line of investigation proceeds from the notion of transmission of traits from parent to offspring in uncertain and varying degrees. The most that such principles could give would be an estimate of probability of inheritance in an individual case. But just at the beginning of the twentieth century the scientific world came into possession of revolutionary principles of heredity which put the possibilities of prediction on a new basis entirely, pointing toward man's being able sometime to speak positively of what will happen in an individual case. This great event was the "rediscovery" of some facts of inheritance in crossing of breeds, worked out nearly forty years before by an Austrian monk named Gregor Mendel, but never adequately published. About the same time, Professor de Vries also "discovered" the obscure journal which contained Mendel's own story of his work, and the law was named for him.

The simplest way to explain Mendelism will be to describe Mendel's experiments with sweet peas. When two varieties of a plant or animal are crossed, the familiar result is offspring intermediate between

the parents though often leaning more or less toward one or the other. But when Mendel crossed a tall variety of pea with a dwarf variety, he found that *all* the offspring in the first generation were tall, and so with other characteristics with which he experimented. This phenomenon had been noticed by Darwin and called "prepotency"; Mendel described it by calling the one trait (tallness, for example) "dominant" and the other "recessive". Mendel's great contribution came in planting the seed from such hybrids and keeping careful records of the offspring for several generations. The plants of the second generation grown from seed produced by such hybrids showing exclusively the "dominant" characteristic, still contained none of intermediate height; but instead of being all tall like their parents, some were pure tall and others pure dwarf, in the proportion of three tall to one dwarf. Continuing the experiment, seed from these dwarf and tall plants were planted separately; it was now found that the offspring of the second generation hybrid dwarfs (the recessive character) were all pure dwarf, and continued to "breed true" indefinitely. The tall plants treated the same way behaved differently. About one-third of them produced seed which yielded only tall plants which bred true, while the seed of the other two-thirds again yielded talls and dwarfs in the proportion of three to one. These dwarfs again continued to breed true and these talls similarly separated into two classes, one-third yielding only talls which bred true, the other two-thirds dwarfs and the two classes of talls in the same proportions of 1, 2, and 1.

Mendel's explanation of this mysterious behavior

This simple experiment brought out several new facts in inheritance. First, we have the fact of unit characters, traits which are not divided, but transmitted either entire or not at all. Second is the fact of dominance, the meaning of which is clear from the description above. And third is *segregation* or the tendency of a hybrid to breed out into two lines, one like each parent. This is obviously of the greatest significance to breeders, since if it can be determined whether a desirable character is a dominant or a recessive, it can be "fixed" once for all, very simply. To explain this regularity of behavior in inheritance on crossing, Mendel devised the theory of "determiners". This theory states, in brief, that an organism is made up of "characters", each of which will be of some one specific type, according to the variety of species or strain inherited. Height, in his sweet peas, is such a character, flower color another, shape of seed another and so on. Each individual is supposed to receive from each parent a "determiner" for each "character". If these two determiners for any character are of different kinds, one will be "dominant" to the other, and the character in the offspring is determined accordingly. The individual in turn, produces germ-cells of two kinds, in equal numbers, containing at random both kinds of determiners, but it only transmits one determiner for each character to its offspring; which one is transmitted is a matter of pure chance.

We can now understand the distribution of traits in successive generations of crosses. The original pure "tall" plant (or that with any other character in a "dominant" form) receives from both parents and produces in its own germ-cells only "tall" determiners, and the dwarf recessive only dwarf determiners. The hybrid receives one tall (dominant) and one dwarf (recessive). The former dominates and the hybrid individual is tall. But its germ-cells contain tall and dwarf (dominant and recessive) determiners at random. When such an individual is mated with one like itself, either a tall or dwarf determiner from plant *A* may unite with either a tall or dwarf determiner from plant *B*. There are four possible combinations, but two of them are alike, so according to the law of chance one-fourth of the offspring receive two tall determiners and are "pure" talls (breeding true), one-fourth two dwarf determiners and are pure dwarfs in the same way, and one-half of them get one dwarf and one tall. Hence

one-fourth of them are like either grandparent and one-half like their hybrid parents. It is precisely like throwing up two pennies at once a large number of times. Approximately one-half of the throws will give one "head" and one "tail", one-fourth two "heads" and one-fourth two "tails". Remembering the simple fact that each individual receives two determiners and transmits one, which is by chance either of those received, we can see the result of the six possible combinations in such a case. Let the letter *D* denote the dominant form of the character and the letter *R* the recessive form. Then

	If One Parent Is a	And the Other a	The Offspring Will Be		
			% *DD*	% *DR*	% *RR*
First Parents	*DD*	*DD*	100	—	—
First Cross	*RR*	*RR*	—	—	100
2d Hybrid generation	*DD*	*RR*	—	100	—
1st Hybrids Crossed with pure strains	*DR*	*DR*	25	50	25
	DR	*DD*	50	50	—
	DR	*RR*		50	50

The "chances" in these other cases can be visualized by supposing that we are tossing two coins one or both of which is alike on both sides, heads or tails as the case may be.

Complications and limits in Mendelianism. Is all inheritance Mendelian?

The simplicity and uniformity of the principles of inheritance as elucidated by Mendel seem to leave nothing to be desired; but a little examination will lead to the impression that the theory raises about as many questions as it answers. The first question, doubtless already in the reader's mind, is this: how are we to reconcile this all-or-none transmission of every trait of either parent with what "common sense" and common observation tell us of the blending of characters? There are two answers, which go a long way toward upsetting the charming simplicity and easy applicability of the theory. In the first place, dominance is found to be an occasional and rather accidental phenomenon. A great many characters do blend completely in the first hybrid generation, though the process of segregation goes on after that as described in the case of the tall and short pea plants. The difference is that the offspring of the first cross, instead of being all like one parent, are all intermediate between the two.

A much more serious complication, accounting further for apparent partial transmission, is the fact of compounding of characters. This may happen in several ways. A trait may be due to two characters with separate determiners, which are transmitted and act independently, either alone giving only half the effect or producing the trait one-half developed. Or, it may be a sum of three, or perhaps more, indefinitely, but beyond that number the possible combinations become almost impossible to trace. Again, a trait may consist of one character modified by another. Thus it has been found in the coloration of rabbits that one character is blackness, while a second added to this converts the black into gray, but the second alone does nothing at all, leaving the rabbit white, just as if both had been absent. This principle also, as will be seen, opens the way to indefinite complications. Another point is that many "traits", in the descriptive sense of the term, are due to the absence of any determiner (as whiteness in the case of the rabbit) and are modified in different ways by the presence of special determiners and in still other, often not clearly related, ways by combinations of determiners.

These various additional principles often make it quite impossible to tell whether the results of a particular cross can be explained along Mendelian lines or not, unless some special clue is discovered, and in other cases a high class of detective work is involved in the analysis. In addition, it should be pointed out that a literal acceptance of Mendelism as a universal law throws us back on some other theory for explaining progressive change, whether natural evolution or improvement by artificial selection. It is impossible to believe that the fancy breeds of dogs, pigeons and fowls, or the increase in the

sweetness of the sugar-beet, the "miracles" of Luther Burbank, and complete transformation of numberless cultivated plants are all the results of segregating out "pure lines". All that Mendelian inheritance can give is obviously a reshuffling of characters already present, and never anything new except in the mode of combination. It can have nothing to say about those real changes, the small scattered variations of Darwin, or the more definite "mutations" of De Vries, which alone can account for the actual cumulative modification of types which the breeder's experience forces us to believe in. In Japan a fancier has evolved by selection a cock with a tail eighteen feet long; separation and recombination of existing characters will not account for this.

Does the Mendelian law of heredity hold good in the case of man?

From our point of view as students of decadence and of the possibility of improving the human type by better breeding, the great question is whether human traits are inherited on the all-or-none principle of Mendel and whether the phenomena of dominance and segregation apply here. It is in the case of man that common sense is most strongly against such a view. Everyone is familiar with race mixture and with the fact that skin color and the other race traits do blend on crossing. It is possible to harmonize these facts with Mendelian principles only by supposing that such traits are not simple characters but very complex combinations. If the blackness of the pure negro is made up of six or eight or more degrees of pigmentation, separately inherited, the results which we see might be explained. But while this saves the theory, it destroys its significance, and throws us back upon statistical investigations such as those of the Biometric School for our only hope of practically useful information. No definite evidence of segregation of skin-color in the descendants of mulattoes has been offered. Professor Punnet reports one or two cases in crosses of the Pacific and Eurasian races with the Caucasian, but they are inconclusive.

Investigations into human heredity are very difficult, because of the small size of families, great length of time between generations, the imperfection of the records and the impossibility of experiment. In addition, the qualities we are most interested in are hard to identify and harder to measure. But in case of definite physical traits, like eye-color and striking peculiarities and abnormalities, definite results are sometimes possible. Some of the characters investigated seem to be unit traits and to obey the simple Mendelian law.

The American eugenics movement along Mendelian lines

Investigation of human heredity has also been making rapid headway in our own country in recent years, and the new movement has from the first been carried on along the line of the Mendelian theories, as it did not get started until those theories were well known. The superior attractiveness of Mendelism is obvious from the practical point of view, as it would make possible definite knowledge of the inheritance of individuals and prediction of its results in particular cases. The American center of study and clearing house of information on the subject of eugenics is the Eugenics Record Office at Cold Spring Harbor, Long Island, founded by the American Breeders' Association in 1910. The director of this institution, Dr. C. B. Davenport, has from the first been one of the foremost eugenic investigators and writers in the country, and several men and institutions have coöperated with him, notably the Training School (for feeble-minded) at Vineland, N. J. The work of this school has driven from the field of interest the earlier studies along more or less biometric lines which had appeared sporadically in this country, such as Dugdale's "The Jukes", McColloch's "Ishmaelites", and Winship's "The Edwards". These were elaborate family histories, the first two of families containing a large proportion of degenerates, and the last contrasting with them a family with a record for conspicuous success and achievement in several generations.

One of the first products of the new movement was the study of the "Kallikak Family", by Dr. H. H. Goddard, of the Vineland Training School. It traces through six generations the history of a family with two branches, founded by the same male ancestor, one with a normal and the other with a feeble-minded woman. Of about five hundred descendants in each line all those in the one were normal and in the other about three-fourths of those for whom data were obtained were classed as feeble-minded, and there was much degeneracy of various forms. The study led Goddard to the conclusion that feeble-mindedness is a simple Mendelian recessive trait, *i.e.*, that all the children of two feeble-minded parents will be feeble-minded. Davenport also makes the same assertion most emphatically, but in a later study of "The Hill Folk" (another degenerate family) Danielson and Davenport concluded that it cannot be considered a unit trait.

Other studies have been put out by the school, but we can only refer to the more notable. One is a study of the inheritance of epilepsy, another of insanity, another of mental abnormalities and so on. Besides the monograph studies, bulletins of the Eugenics Record Office, and a book by Davenport, "Heredity in Relation to Eugenics", contain evidence as to the inheritance along Mendelian lines of a great variety of human characteristics, deformities, aptitudes, diseases and the like. The material for these studies is derived from data secured by correspondence with individuals and from the family histories which the public is invited to furnish to the office in the interest of science. The later studies have shown a tendency to be more cautious than some of the earlier ones. The authors are getting away from their former cock-sureness about the applicability of Mendelism and the simplicity of human traits. This caution characterizes the conclusions of Professor Bateson, the great English exponent of Mendelism, who first translated Mendel's paper into English and made careful studies in the theory and in particular with reference to its applicability to human inheritance. He decided that, on the question of its validity in the case of man, judgment must be suspended pending further investigation. The English school of eugenists, the biometrical school, has been as dogmatic in its assertions of the irrelevance of Mendelism as the American school is or was overconfident of the results to be quickly achieved by the method. As so often happens in such cases, investigators in closely related lines have held aloof from each other on grounds of methods instead of coöperating on the ground of common aims, as the interest of science demands. There is really nothing antipathetic about the two methods, and they should be made to supplement each other.

What we really know. The progress of the propaganda

It should not be inferred from the tone of skepticism in the foregoing discussion that the eugenics movement has been altogether devoid of significant results. This is very far from being the case, even though the crucial problems are still a long way from definitive solution. The young eugenics movement has already a great deal to its credit, perhaps as much as should be expected or as is desirable at the present stage of its development, for it is always well that the best of changes, if of a far-reaching character, should come about gradually. In the first place, then, we know that it is an important question, and the public has been fairly well aroused to its importance and made to realize the absolutely crucial significance of the quality of the breed of men for the permanence of any other good which one may be working for. A fair index of the appreciation of the subject is the amount of discussion which it arouses in the literature of the time. The rapidly lengthening list of popular books and the rising flood of articles in every class of serious periodical show that the reading and thinking public is waking up. The Eugenic Education Society was founded in England in 1907, and started the *Eugenic Review* in 1909. Societies have also been founded in France and Germany.

In the second place, though the scientists have not yet given us practically applicable laws of inheritance — still less means of predicting the character of the children of any particular union — yet the work along these lines has emphasized the fact that both conspicuously desirable and undesirable traits are strongly hereditary. That "blood tells" is becoming a fact of scientific and even practical importance as well as an aphorism to be bandied about in polite literature and conversation.

The importance of negative eugenics recognized by society

These two facts are even beginning to be made the basis of some private and even public action looking toward human betterment. A bigger proportion of intelligent and educated young people are beginning to see in their prospective mates the other parent of their future families and to consider the question of heredity as well as personal congeniality. Beyond this education of the individual and the stimulus to take account of eugenic facts in making his plans for life, we have not yet gone and cannot yet wisely go on the side of positive eugenics. Our knowledge of heredity is still too limited even to lay down rules for guidance, much less try to enforce rules by public authority in this field. On the side of negative eugenics, science is in many respects on much surer ground. Physical defects and even positive mental abnormality and deficiency are fairly identifiable and their hereditary character is well established. Consequently society is fairly safe in bringing the pressure of public opinion to bear to prevent the multiplication of persons of these classes, and even in taking authoritative steps in the same direction.

There is one phase of the problem of racial quality that comes home to the average man in a way to which he is always sensitive, that is, through his pocketbook. The whole country, one may say, has been seriously alarmed over the rapid increase in the burden of caring for the defective classes in recent years. In some of our older states a very large fraction of the total revenue goes for this purpose. Statistics show a striking increase in the proportion of such unfortunates in the general population. Probably a good part of the apparent change is due to our higher humanitarian standards and the relative growth of institutional methods of care and to improved statistical data. However, there is little doubt that as the general birth-rate falls that of the defective classes remains relatively fixed, and it is probable that they get their full share, if not more, in the decrease in the death-rate. The evidence that degeneracy runs in families seems conclusive and some forms of criminality no doubt have also a hereditary basis. In any case the demand of the tax-paying public for the cessation of the breeding of people who are a burden to themselves and to society as well is entirely intelligible.

Progress toward elimination of the definitely unfit

The biometrical and the Mendelian schools of eugenists are in practical agreement that positive eugenics is still a matter for individual education rather than public action, and also that certain defectives, especially the feeble-minded, insane, epileptic and congenitally deaf, transmit their defects to their offspring in such a large proportion of cases as to justify society in preventing their multiplication. It is then a question of method. One way suggested is to require certificates of fitness for marriage, and some laws along this line have been passed by American states, notably Wisconsin. In addition some twenty states forbid the marriage of various classes of defectives. The objection is that marriage is not separated from parenthood. The absence of legal marriage does not prevent cohabitation or reproduction, and on the other hand it would be very desirable to permit marriage if there were some practical way, moral or other, of preventing reproduction. The most rational method of dealing with the question is by surgical sterilization, which can be done for either sex painlessly and without affecting the normal emotions or functions, and does not interfere with the mode of life of the individual in any

other way than to prevent his transmitting life to offspring. Public sentiment, or popular prejudice, whichever one pleases to call it, is, however, against such procedure, and it is probably politically inadvisable at the present time. Sterilization laws have been passed in a dozen states but they are practically "dead-letters".

The only other method is segregation, and this is the most strongly advocated as a practical expedient. It would be enormously expensive and in any real sense is much more of a hardship to the individual concerned as well, since it not only prevents reproduction—all that sterilization would do—but *in addition* subjects him to incarceration for the better part of his life. However, if it is the only practicable way, it is probably cheaper in the long run than having the defectives as an ever-growing social burden, and should be resorted to in positive cases. It would seem reasonable at least to give the individual his choice between this treatment and sterilization. The principal practical problem is that of feeble-mindedness. There are supposed to be at least 200,000 such persons in the United States, of whom perhaps one-tenth are cared for in proper institutions and another tenth in poor-houses, jails, insane asylums etc. Feeble-mindedness is the physical, heritable basis, where there is one, of most other forms of degeneracy, criminality etc., and is the only one which is normally in any great degree free to reproduce itself. Whatever our feelings in regard to these matters, they constitute a problem which society will one day be compelled to face and take decisive action upon, and the longer it is put off the worse the situation will become.

PREPARING FOR WORK IN THE LARGER VINEYARDS

Activities in the gardens of the Training School at Vineland, N. J., devoted to the interests of those whose minds have not developed normally.

NATURALISTS AND BIOLOGISTS VII

ELIE METCHNIKOFF — AND THE POSSIBILITY OF PROLONGING LIFE
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JOHN TORREY — ONE-TIME CHIEF OF AMERICAN BOTANISTS
ADDISON E. VERRILL — DISTINGUISHED AMERICAN ZOÖLOGIST

ELIE METCHNIKOFF
And the Possibility of Prolonging Life

ELIE (ILIYA) METCHNIKOFF, the distinguished biologist and bacteriologist, was born of Jewish parents at Kharkoff, in Russia, on May 15, 1845. He was educated at the Gymnasium and the University of Kharkoff, passing through the department of science, and then, went on to Giessen, Göttingen and Munich for research in zoölogy, after which he was appointed professor of that subject at Odessa. He made various zoölogical expeditions — to Madeira, Teneriffe and the Kalmuck Steppes — at this time. In 1882 he devoted himself specially to bacteriology, and in 1888 he went to the Pasteur Institute in Paris. After the death of Pasteur, which occurred in 1895, Metchnikoff succeeded him as director of the Institute, which position he held until his death, there, on July 15, 1916.

The young Metchnikoff, as a zoölogist, spent many years in studying the development of insects, worms, jelly-fish, sea-urchins and many other lowly invertebrate animals. Not even he could then have guessed that "from these remote, inhuman interests" he was soon to pass "without intellectual transition to results affecting vitally the human race." But it was so. "From observations made originally on water-fleas, he was led to discover the functions of the white corpuscles of the human blood. He showed by what mechanism these made perpetual war against the intruding microbes of disease, and he laid the foundations of our knowledge as to the agencies that weaken or that strengthen these guardians of our health. In a series of investigations into the phenomena of inflammation in men and lower animals, he carried his observations into new fields, and explained the relations of the white corpuscles to the juices that attract and repel them."

Professor Metchnikoff's book on "Immunity in Infective Diseases" has been translated into English, and is a classic upon the subject. His initial discovery of the function of the white cells of the blood, which he taught us to call the "phagocytes" or eating-cells, opened the way to further great advances, which have notably been taken by Ehrlich in Germany. For some time Ehrlich's view came to be generally entertained — that the white cells do not do the essential work of protection, but that they devour invading parasites after the task has been made easy through the poisoning of the parasites by substances which have first come into action. But Metchnikoff argued that, in point of fact, the substances which act upon the parasites, so that the phagocytes can digest them, are first produced by the phagocytes; all the honor rests with them.

At the present time the study of immunity centers round this problem, and on the whole it is fair to say that the most recent evidence has tended to restore our estimate of the phagocytes to the level set by Metchnikoff over a quarter of a century ago. They do produce powerful ferments, the most important of which is trypsin, and by this means they do wonders for the protection of the body. Hence the latest method of treating tuberculosis, and helping the phagocytes to kill the microbes, is by the injection of trypsin into the affected part. Professor Metchnikoff's later researches on the ways in which the phagocytes may be helped or hindered in their work, especially his detailed studies of alcohol, which he proved intoxicates the white cells and therefore must be entirely banished from medical practice in all diseases due to microbes, has had a great effect upon medical methods during the last dozen years.

In 1908 Professor Metchnikoff was awarded the Nobel Prize in medicine. It had been well earned, above all for the fundamental discovery upon which modern theories of immunity and susceptibility must depend, and afterwards for the long researches by which he was able to direct the practice of hygiene in so many respects. Late in 1912 Professor Metchnikoff gave a lecture on "The Warfare against Tubercle" which was a most important pronouncement. In it he presented arguments to show that recovery from certain types of infection by tuberculosis confers an immunity against subsequent attacks. He held that this "natural vaccination," so to call it, against tuberculosis largely occurs in cities today, and that it, above all, accounts for the great fall in the tuberculous death-rate which has occurred in most parts of the civilized world during the last half-century.

It is astonishing that so little notice was taken of the expression of this startling yet entirely reasonable theory by the greatest of authorities. The immediate duty of science is now to discover whether the theory is true. Professor Metchnikoff hoped that it might be possible to find and cultivate mild strains of the tubercle bacillus which can be used for purposes of protection by acquired immunity, on exactly the same principle as the use of vaccinia, which is modified smallpox, for protection against that disease. Meanwhile, the view is extremely disconcerting to those who have supposed that the presence of tubercle bacilli in milk is an unmixed evil.

Two books were written by Professor Metchnikoff for the educated public. The later and less important is called "The Prolongation of Human Life", and deals mainly with the theory that man's life is unnaturally shortened by the poisonous products which are formed in his alimentary canal by certain microbes. Hence Metchnikoff introduced lactic acid as an ingredient of diet, since the dangerous microbes can only live in an alkaline medium, and lactic acid will destroy them. Evidence in favor of this theory was found by Metchnikoff in the great longevity of the Bulgarians, who live largely upon sour milk. Metchnikoff had taken such milk himself for many years, and his example has been widely followed, the hope being that the microbes which produce the milk-acid will live in the bowel, and control those which produce the alkaline poisons. Time is still required before we can decide upon the value of this method, but it is certain that Metchnikoff's theory is sound; and the only question seems to be whether lactic acid, taken by the mouth, can ever reach, without first being neutralized, the remote coils of the bowel where its action is required.

More important is the notable book on the "Nature of Man". In these "studies in optimistic philosophy", to quote their sub-title, Professor Metchnikoff argues that man, descended from animal ancestors, still has within him a number of "disharmonies", of structure and foundation, which gravely hamper and endanger him in the new and higher life which he now leads. These disharmonies must be studied and understood, in the light they throw upon the nature of man, and then we must do what we can to remove or control them. Such views are now established and appre-

PROFESSOR METCHNIKOFF AT WORK IN HIS LABORATORY

ciated by all reasonable men, and they look largely to science as the instrument by which the part of man's nature called the intellect may more than compensate for the many disharmonies of his constitution. In the great warfare with disease the name of Elie Metchnikoff will always remain that of a leader and a prophet.

SILAS WEIR MITCHELL

Neurologist and Author

THE purely perfunctory part of Dr. Weir Mitchell's history shows that he was born in Philadelphia on February 15, 1829. His father, John Kearsley Mitchell (1798–1858), was a Virginian and a physician. He established himself in Philadelphia in 1822, where as a practitioner and professor of medicine and physiology at the Philadelphia Medical Institute (1826), professor of chemistry at the Franklin Institute (1833) and (1841, till his death) professor of the theory and practice of medicine in the Jefferson Medical College he earned a wide reputation in his profession.

Weir Mitchell was one of nine children and after his first schooling in the old grammar school of the University of Pennsylvania, praised by Franklin for its standards, he passed from the university to the Jefferson Medical College, from which he graduated in 1850 at the age of twenty-one. He then began the practice of his profession in Philadelphia, devoting to it great energy and earnestness. At twenty-three he published his first medical paper, succeeded afterwards by over a hundred, with a score besides on subjects more scientific than medical. He was living at this time in an atmosphere that encouraged his bent towards the professor's life that his father's had been. A happy fate saved him for better things. The Civil War brought that flood of clinical material which was to recast the practice and restate the principles of American medicine. Tens of thousands of cases of injured nerves coming in for treatment set in ordered discovery their action and reaction. Dr. Weir Mitchell became an army surgeon and assumed special charge of soldiers suffering from nervous disorders and from injuries which directly affected the nerves. A volume, "Gunshot Wounds and Other Injuries of the Nerves", presenting the results of his studies in the hospitals, appeared in 1864. He spent three years in this work and at the close of the war had determined upon neurology as his special branch of medicine. Out of the long observation in the years that followed there was slowly evolved that complex and balanced nursing of ex-

hausted and deranged vital faculties — their ebb manifest in nervous disorder — which has come familiarly to be known as the "rest cure", and on which Dr. Mitchell's wider fame as healer rests.

Meanwhile he had used some of the material he had picked up in the army hospital in a short story. The story was the result of a discussion with other physicians regarding the effects on a man's individuality of the loss of members. In "The Case of George Dedlow" the patient had had both legs and both arms amputated. The *Atlantic Monthly* in 1863 carried the story as its leading feature and it aroused great interest; subscriptions poured in from sympathetic readers for the unfortunate "Dedlow" which were returned with the explanation that his was an imaginary case.

This was practically the only occasion on which Dr. Mitchell wandered into literary paths for nearly twenty years. He wrote prolifically, but on medical topics. "Wear and Tear" (1873) and "Rest in the Treatment of Disease" (1875) explained in detail his "rest cure". A swarm of lesser papers followed — the largest and most extensive group of these deal with the venom of serpents, and embodied the observations of twenty years, culminating in two monographs. All of them are replete with scientific spirit, many of them record fresh observation and discovery, or shed new light on old problems.

In the late '70's Dr. Mitchell had attained a place in his profession which he considered entitled him to turn to the writing of fiction and verse as a recreation. After 1880 there appeared over his name seven novels, two books of fairy stories, four poetic dramas, six slender volumes of verse, and essays, addresses and brief articles ranging over all the field of medicine and dealing with many phases of both medicine and science. Much of it challenges the highest place, or one just short of it.

"Hugh Wynne, Free Quaker", the most widely known of Dr. Mitchell's stories, appeared in 1897, achieved immediate success, and at the age of sixty-eight its author jumped into a leading place among contemporary American novelists. The novel has woven into it the story of this country's fight for independence. The hero, a young Quaker, goes to war in spite of his religious associations. Talcott Williams in his account of its author says, "Life, skill and the moment joined. The intimate knowledge of the nature of men and women; the personal acquaintance with the Revolution, local, traditional, by residence, by descent, by kin, and by marriage; the sense of the American ideal of gentlehood, loftier and more uncompromising than the European, and breathing a freer air, higher and more secure; the serene confidence in the national movement, based on even-footed acquaintance with the Old World and the New; the constancy of character and principle — these all met and mingled in this romance, just as the nation itself had unawares reached a new resolve to take its place on the world's stage and play its fit part in the responsibilities, the rewards and the sacrifice of empire."

"The Adventures of François" followed a year later, "Dr. North and His Friends" appeared in 1900, along with the "Autobiography of a Quack" and "The Wager". Then at short intervals appeared "Circumstance", "Pearl", "Comedy of Conscience", "Little Stories", "The Youth of Washington", "Constance Trescott", "A Diplomatic Adventure", "The Mind Reader", "A Christmas Venture", "The Red City", "The Comfort of the Hills" and "John Sherwood, Ironmaster".

Dr. Mitchell died January 4, 1914. Not only by his community, but by his country and the world, was he held in esteem and honor. "Physician, novelist, poet, man of letters and of affairs, discoverer in science and in medicine, familiar through a long life with the best, and giving of the best, sharing our heroic period in his early manhood and aiding in later years to inspire and awaken a new national ideal it is well to remember when we deplore our loss his line, 'Death's but one more tomorrow,' written — in curious antithesis — 'On one who seemed to have failed'."

HUGO VON MOHL
Vegetable Anatomist

HUGO VON MOHL, the acknowledged chief of the vegetable anatomists of his generation, was born at Stuttgart, April 8, 1805, the youngest of four brothers who all became men of mark in political and scientific life; Julius the orientalist and Hugo the botanist being the most distinguished. The latter was educated at the Stuttgart Gymnasium and Tübingen University, where he studied medicine as well as natural history and physics. His first publication, while a student in the year 1827, was his "Essay on the Structure and Soiling of Tendrils and Twiners", written in response to a prize question offered by the Tübingen Medical Faculty. In it he endeavored to show that the stems have a dull kind of irritability, so that they bend towards any object which they touch. Darwin has given us better knowledge of the phenomena, but bears witness to the *prima facie* probability of von Mohl's view. In the following year appeared his inaugural dissertation on the "Pores of the Cellular Tissue of Plants", in which his later views and discoveries, respecting the structure, growth and component parts of cells, as subsequently developed, are already foreshadowed. The paper gave the first account of the true structure of the dots or "pores", showing they were thinner portions of the cell-membrane.

It was his father's wish that von Mohl should devote himself to surgery. This, however, was distasteful to him and he decided upon a scientific rather than a medical career; and went to Munich to pursue more advantageously his botanical investigations, which by degrees became his great object in life. He entered on his task not only with the great advantage of a mind highly cultivated in the collateral sciences, as well as in the languages, but also in early days, possessed of a robust frame and constitution which served him in his excursions in his own neighborhood and in the Alps, as he gathered extensive collections of plants and accumulated materials for future study. At this time he began his researches into the anatomical structure of the palms, ferns and cycads, and in 1831 contributed to the great work of Martius on palms a memoir on the structure of the stems of those plants. Von Mohl's paper dealt the final blow to the theory of the internal growth of monocotyledonous stems first propounded by Desfontaines, and upon which De Candolle had founded the division of vascular plants into exogens and endogens. It is in this memoir, that he appears to have first described the origin of ducts from rows of closed cells, a point which he further developed in the following year in a paper, "*Ueber den Bau der porösen Gefässe*".

His merits were promptly recognized by a call to the imperial botanic garden of St. Petersburg as assistant to its director, an invitation, however, he did not accept, owing to his appointment as professor of physiology at Berne, whither he went in 1832. After the death of Schübler he returned in 1835 to Tübingen as professor of botany in the university; and here remained, notwithstanding brilliant proposals tempting him elsewhere, till the time of his death. The interests of the university were matters of keenest solicitude to him, and the foundation of a faculty of natural science was essentially his work. In 1843 he was raised by the king of Würtemberg to the rank of nobility. About this time he was obliged to make a prolonged stay in South Tyrol on account of delicate health. He recovered, but although a man of great stature and robust build, appears, after his sixtieth year, to have fallen into chronic ill-health. Eventually he became very reserved in manner. On the morning of Easter Monday, April 1, 1872, having been cheerful and well the night before, he was found dead in bed.

To describe von Mohl's scientific career and position would be to write the history of vegetable histology. His work is practically coincident with the application of the higher powers of the microscope to the investigation of vegetable tissue. Confining himself almost exclusively to the higher classes of plants, from the group

of Muscineæ upwards (and neglecting the Algæ, Fungi and Lichens) there is hardly a point of any consequence in which some research or investigation of von Mohl's is not the solid formation of our present knowledge. Although he published some ninety papers, he resolutely declined to bring out any general work. His "*Mikrographie*" (1846) and his "Principles of the Anatomy and Physiology of the Vegetable Cell" are the only writings which may claim to be such. His own labors were not the only in which he contributed to the advancement of our knowledge of the minute anatomy of plants. In 1843 he founded, in conjunction with Schlechtendal, the *Botanische Zeitung*, which he continued to edit until his death. The volumes of this periodical chronicle, year by year, the gradual development of the microscopic study of plants, a field in which German science has perhaps reaped a more abundant harvest than that of any other nation.

LEWIS HENRY MORGAN
First Scientific Observer of an Indian Tribe

LEWIS HENRY MORGAN, the American ethnologist, was born near Aurora, New York, on November 21, 1818. He was graduated in 1840 from Union College, then studied law and was admitted to the bar; forming a successful partnership with a classmate, George F. Danforth, he practised his profession in Rochester, N. Y.

Soon after leaving college Morgan went among the Iroquois, living as far as he could their life and studying their social organizations and forms of government. He was adopted into the Hawk gens of the Seneca tribe, being named "Ta-ya-da-wah-kugh." At the same time he organized a society of young men called the Grand Order of the Iroquois, who like their founder adopted the study of that tribe. His researches were published in "The League of the Iroquois" in 1851, and were noteworthy as forming "the first scientific account of an Indian tribe ever given to the world." In 1856 Morgan became acquainted with Agassiz, who took great interest in his work and exhorted him to continue it.

Discovering that the system of kinship of the Ojibways was practically the same as that of the Iroquois, Morgan pursued his investigations along that line, and in 1868 the Smithsonian Institution published his "Systems of Consanguinity and Affinity of the Human Family", and in 1877 he himself published his "Ancient Society, or Researches in the Lines of Human Progress from Savagery, through Barbarism, to Civilization".

In the history of ethnology Morgan's name ranks high. Influenced by the views of Darwin and his contemporaries he is the only American belonging to that group of anthropologists who believed that the evolutionary point of view and the law of progressive development held for all forms of culture. That, for instance, all peoples passed from a hunting to an agricultural mode of life as a necessary step in development, and that therefore genetic relationship existed between all groups ranging from lowest savagery to highest civilization.

That period has passed and anthropologists today reject the theory of evolution in so far as it is applied to cultural development, holding that its phenomena are not hereditary but perpetuated by education and imitation, and should therefore be studied from the historical and not the biological standpoint, involving field research, excavation and analysis of archæological remains. Nevertheless, Morgan's place will "ever remain a high one since his labors have been the point of departure for most modern speculation and concrete research on social evolution".

JOHANNES MÜLLER
A Great Physiological Thinker

JOHANNES MÜLLER was born at Coblenz on July 14, 1801, and from 1824 to 1833 studied and taught physiology in the University of Bonn. There his work gained him such distinction that in the latter year he was appointed professor of anatomy and physiology in the University of Berlin, and there he remained for the rest of his life.

Like other physiologists, Müller made many researches into the details of his

science, and his work extended also to comparative anatomy, where he studied the lancelet, the fishes and sea-urchins in especial. His physiological observations dealt with the blood and with the mechanism of speech, among many other subjects. But his name will always be remembered as that of a great physiological thinker — the numbers of whom in all time are scant indeed, though capable physiologists are always plentiful. Müller has indeed been often ranked as the founder of modern physiology; and his great work, the "Handbook of Human Physiology", which was published during the 'thirties of the nineteenth century, made an epoch, thanks to the profound intellectual powers of its author.

Physiology needed a thinker. Facts had been collected, with great speed and of great consequence, in the generation before Müller's time; but a multitude of facts is not a science, any more than a heap of stones is a cathedral. Müller resolved the chaos of data into a cosmos. He thus became the greatest teacher of physiology that this science has ever known. The masters who have since flourished in Germany, from the illustrious Helmholtz down, were nearly all pupils of Müller, and ungrudgingly acknowledged their debt to him.

His most important and profoundest contribution to his science was the generalization which is now known as "Müller's law". It is sometimes also called the "law of specific nervous energy". It states the remarkable truth, discovered by Müller, that the sensations we experience depend upon the innate powers of the sensory centers concerned; so that if *any* agent excites the center for vision or the center for taste, vision and taste are respectively experienced. Not light merely excites vision, but also pressure and electricity. Subtler internal causes may excite vision also, as in dreams; but if the visual center acts, *vision and nothing else* results. This discovery carries us far into the mysterious depths of physiological psychology. Johannes Müller died on April 28, 1858. His native city erected a monument to his memory in 1899.

MAX NORDAU

Does Civilization Lead to Degeneration?

MAX SIMON NORDAU is the name assumed by the brilliant son of a Hungarian Jewish scholar, Gabriel Südfelt. Born in Pest on July 29, 1849, Nordau was educated as a medical man in his native city, but turned to journalism as a means of livelihood, and spent some six years in traveling about Europe. Vienna, Berlin and Paris were the cities in which he stayed the longest, but he roamed from Russia to England, and from Scandinavia to Spain and Italy. In 1878 he settled down in Pest, and began to practise as a doctor, but apparently he did not find medicine as lucrative as journalism, and at the end of two years he went to Paris as a special correspondent. And there he remained.

Nordau began his career as a journalist in 1872, when he joined the staff of the *Pester Lloyd*. Later he wrote serial stories for that journal; and the *Frankfurter Zeitung* and the *Vossische Zeitung* published much of his work. After 1881 he was Paris correspondent for the last-named German paper. His career as a journalist and as a writer of feuilletons must be taken into account in discussing his work as a man of science. Nordau has never lost his love of creating a sensation; he has something of a journalist's delight in making a "scoop", and he certainly works out his ideas for all that they are worth.

His early medical studies led him to take an interest in the researches of Lombroso into the signs of nervous and intellectual degeneration. Suddenly it struck him that the evidence which the Italian man of science had collected among the criminal classes of Italy could be applied in diagnosing the poets, painters and writers of the decadent school in France. It was notorious that some of the French bohemians of the period were leading unhealthy lives. Nordau mixed with them for a while, studying them with the eyes of a journalistic physician with a theory to prove. Naturally, he was able to prove that a poet who habitually took absinthe as a source of inspiration was a degenerate. But he went on to show that,

from his point of view, almost every composer, poet, novelist and painter of genius in modern Europe was an example of "degenerate psychoses of the epileptic group". It seemed as though the genius and the criminal were both madmen, and that the insanity of genius was undermining civilization. Only in sane philistinism was there any refuge from the asylum.

Nordau's own genius for exaggeration was a marked characteristic of his famous work on "Degeneration". Appearing in 1893, the book made a sensation throughout the civilized world, for there were undoubtedly at that time signs of decadence in literature and art. In England men of the stamp of Aubrey Beardsley and Oscar Wilde had introduced something sinister into the intellectual life of the nation; things were still worse in France, and as bad in Germany and Italy. The weakening of religious faith, the spread of luxurious habits, and the passion for novelty at any cost had led some writers, painters and musicians into perilous paths, but the entire movement was a shallow and a passing thing. It did not affect the general life of the people, and it soon lost its force. "Degeneration", which was dedicated to Lombroso, had for its theme the relation between genius and degeneracy. "It was a vigorous polemic against vice or abnormality and a eulogy of decency in literature and art, at times approaching prudery." If the work is immoral the author is a degenerate and not a genius.

Nordau took it and himself too seriously. He fastened his label of insanity on everything and everybody he disliked — on Wagner and his music, on Tolstoy and his novels. In his hands "degeneration" became not a theory but a bludgeon, and he tried to strike down every figure of importance in European art and letters, with the exception of a few men who, like Gerhard Hauptmann in his play "The Weavers", used their art to forward the doctrines of social democracy. In recent years Max Nordau has been closely associated with the Zionist movement for resettling the Jews in Palestine.

THOMAS NUTTALL

American Botanist and Ornithologist

NUTTALL was one of that great trio of naturalists, Wilson, Audubon and himself, that brought so much credit to this country in the early days of the Union. He was an Englishman, the son, born in 1786, of James Nuttall, a printer in Blackburn, near Liverpool. As a lad he worked in his father's shop, but all his leisure was given to the study of the plants and animals of his neighborhood. Longing to explore new lands, and see other floras, he left England when 22 years old, and in March, 1807, came to Philadelphia. Here he became acquainted with Benjamin Barton and other naturalists (Philadelphia was then the center of scientific work in the United States), and under their encouragement devoted himself to the study of nature. In 1811 he began the first of those journeys which yielded him so much new knowledge, by ascending the Missouri River almost to the Rocky Mountains in the company of John Bradbury, whose "Travels" (London, 1817) record this enterprise. Subsequently he took several other extensive journeys, often involving much hardship, as when he penetrated to the Everglades in Florida, when he followed the Arkansas River far toward its source (1819) and when he finally crossed the continent.

Nuttall had by this time become well known. He had prepared and issued his "Genera of North American Plants" (Philadelphia, 1818); had written a "Geological Sketch" of the Mississippi Valley; and in 1821 published his "Journal of Travels into the Arkansas Territory". It is not surprising, then, that when the death of Dr. W. D. Peck, who had founded the Botanical Garden at Harvard College in 1805, left the office of its curator vacant, Nuttall should have been called to succeed him. He moved to Cambridge in 1822, and applied himself with the zeal of a man eager for research to the advancement of the garden, and to field-work. Asa Gray, his distinguished successor, wrote of him: "Probably few naturalists have excelled him

in aptitude for such observations, in quickness of eye, tact in discrimination, and tenacity of memory". Meanwhile he developed those quaint personal characteristics which have made him smilingly remembered as the type of the unworldly "naturalist" of the cartoonists and the comic stage. He occupied two rooms in Professor Peck's house, one on the ground floor, from which he cut a special entrance to the Garden merely to avoid the chance of meeting anyone at the adjacent front door. For greater seclusion he avoided the stairs, and reached his sleeping apartment above by means of a trap-door in the floor and by the aid of a step-ladder; and a panel, hung on hinges in the door which connected with the kitchen served for the passage back and forth of a tray upon which his meals were served. It had been expected that he would give lectures, and other instruction, but he did little or nothing of the kind. He wrote, however, "An Introduction to Botany" (Boston, 1827).

One important by-product of this period was the publication of his "Manual of the Ornithology of the United States and Canada" (Boston, Vol. I, "Land Birds", 1832; Vol. II, "Water Birds", 1834). He was thus an exact contemporary of Audubon; but they seem to have paid little attention to one another. This work is a classic, the original edition of which is scarce and costly. Its descriptions are remarkable for a close knowledge of both the affinities and the habits of our birds, together with a highly poetic appreciation of the charm of their manners. No one has tried to portray their songs so fully; and his preface is one of the most admirable essays in the literature of ornithology. It is by this book, rather than by his botanical work, that he is best known; and the impression it leaves with the reader is that his queer attitude toward society arose from shyness and a sense of the value of time, rather than from crustiness. A memorial to him exists in the name of the Nuttall Ornithological Club, organized about 1873 by young bird-lovers in Cambridge, out of which grew the American Ornithologists' Union.

Just as the "Manual" was off the press, Captain Nathaniel Wyeth, of Cambridge, who had lately returned overland from the Pacific Coast, organized an expedition to go to Oregon by way of the South Pass, and offered to collect plants for the Botanical Garden as he had done before. Instead of this Nuttall proposed that he himself should join the party. Wyeth having agreed to this, Nuttall resigned and went with the expedition. Another of the party was the naturalist J. K. Townsend, who wrote a "Narrative" of it (1839), in which much may be learned of Nuttall's original personality.

THOMAS NUTTALL

Although he was, like all ornithologists, eager to find and study new kinds of birds, he rarely used a gun; and on one occasion, in the Rocky Mountains, where danger from hostile Indians was imminent, and all the guns in the party were inspected, Nuttall's fowling-piece was found to be stuffed to the muzzle with bulbs! From Oregon Nuttall went to California, then sailed to Hawaii, and, after a period of collecting plants there, returned to the United States around Cape Horn in the vessel that had in its crew Richard H. Dana, author of "Two Years before the Mast".

Nuttall then renewed his residence in Philadelphia and worked on his collections and on the preparation of a supplement to Michaux's "Sylva", which was published in three volumes in Philadelphia between 1842 and 1849. In the former year the death of an uncle required his return to England to take possession of an inherited estate in Nutgrove, Lancashire. There he made a private botanical garden, and lived quietly but busily for several years, with occasional visits to America, until his death on September 10, 1859, in his 83rd year.

SIR WILLIAM OSLER
A Cosmopolitan from the New World

SIR WILLIAM OSLER, the physician and author, was born at Bondhead, Ontario, on July 12, 1849, the son of a clergyman. He was one of four brothers, all of whom attained distinction, two in the law, the other in finance. Sir William was educated for the medical profession at Toronto, Montreal, London, Berlin and Vienna. His first academic appointment was the chair of medicine at McGill University, Montreal, in 1874. Ten years later he became professor of clinical medicine in the University of Pennsylvania; and five years later professor of the practice and principles of medicine in the Johns Hopkins Medical School and chief physician to the Hospital. From this appointment he passed to Oxford as Regius professor of medicine in 1905 and thereafter resided in England. Sir William received honorary degrees from many other universities besides those with which he was associated as a student or teacher. He served as president of the Association of American Physicians in 1895.

His contributions to literature cover a very wide range. They include not only "The Principles and Practice of Medicine", and, as editor, "A System of Medicine" in seven volumes, with a number of publications on special studies of obscure forms of disease, but also addresses to students on the human side of their profession — their relation to patients, nurses and the public. At Harvard he widened the range of his topics by an address on "Science and Immortality", in which he expressed the opinion that in scientific circles faith is no longer diversified by doubt, but doubt is diversified by faith. He, however, would rather, like Cicero, be mistaken with Plato, if it be a mistake, than be right with those who deny the life after death.

Sir William Osler had a great reputation in the United States for his power of diagnosis by a kind of instinctive insight — the most physicianly of all qualities — and as a stimulator of the students who came within the range of his personal influence. He made a special point of urging his students to keep abreast not only with medical practice, but with the thought of the times, so as to preserve the mental freshness and breadth of outlook which they, perhaps most of all men, need. His own success is a proof of the fact that the physician's influence is largely a question of masculine sense and personality. On leaving America in 1911 he made a much quoted address in which he referred to "the comparative uselessness of men over forty years of age," and said, "take the sum of human achievement in action, in science, in art, in literature; subtract the work of the men at above forty . . . we should practically be where we are today." This was distorted into "too old at forty" by a press eager for catch lines. Osler himself was the living refutation of such a theory. He died at Oxford on December 29, 1919.

SIR RICHARD OWEN
A Reader of History Written in Bones

SIR RICHARD OWEN, one of the most famous of comparative anatomists and paleontologists, was born at Lancaster, England, on July 20, 1804, younger son of a West India merchant. After attending the local grammar school, where he showed no indication of the talent latent in him, he was apprenticed at sixteen to an apothecary and surgeon. With other pupils, he was given access to the county jail, where they were permitted to conduct post-mortem examinations, and he became greatly interested at once in the study of comparative anatomy.

He passed from Lancaster to Edinburgh University, where he matriculated, and underwent the training proper to the career of a surgeon, but went to London for his diploma, intending all the time to join the navy as a doctor. At this period his career greatly resembled that of Huxley. He was disappointed of his hopes; so, simply to mark time, and keep body and soul together, he accepted a minor position in the Royal College of Surgeons, as assistant to Clift, John Hunter's most devoted assistant. Owen joined Clift in the Hunterian Museum of the College. Here was the richest collection of anatomical specimens that had ever been got together in the history of the world. The government had bought them at the death of Hunter, and here they were, after forty years, uncatalogued, useless. It fell to the lot of Owen to catalogue and arrange them, and the result of his labors was an incomparable series of monographs, and, later, a valuable edition of the works of Hunter himself. He interpreted Hunter to the world, and gave to humanity the wonderful story revealed by the magnificent collection got together by that prodigy of zeal and wisdom. In course of time, Owen married the daughter of Clift, and succeeded her father as curator.

The young couple had rooms at the College of Surgeons, and their home developed into the strangest museum in the world. Owen undertook the dissection of all the animals that died at the Zoölogical Gardens. Many of them were taken to his rooms; and the dinner of the young people would be interrupted by the arrival of a dead lion or kangaroo, a bear or a baboon, a crocodile or a pelican. He lectured and wrote upon physiology, upon paleontology, upon morphology. His investigations covered the whole range of animate creation, from sponges to man. He was opposed to the Darwinian theory. His influence upon the learning of his age was unbounded. Lecturer, writer, demonstrator, called to adjudicate at exhibitions, and to sit upon important commissions, he grew in power and repute with all but the people who should have assisted him. He might call at Buckingham Palace and Windsor Castle, and lecture to the royal children, but official England was as hopelessly uninterested in science as it was when Melbourne insulted Faraday. Consequently, Owen, whose reputation was now practically world-wide, remained poor.

We find Macaulay, friend to learning, very anxious about the affairs of Owen in 1856. He is writing to the Lord Lansdowne of the period, urgently suggesting the reform of the British Museum, and the installing of Owen in charge of the department devoted to geology, zo-

SIR RICHARD OWEN

ology, botany and mineralogy. "I cannot but think," he wrote, "that this arrangement would be beneficial in the highest degree to the Museum. I am sure that it would be popular. I must add that I am extremely desirous that something should be done for Owen. I hardly know him to speak to. His pursuits are not mine. But his fame is spread over Europe. He is an honor to our country, and it is painful to me to think that a man of his merit should be approaching old age amidst anxieties and distresses. He told me that eight hundred a year, without a house in the Museum, would be opulence to him. He did not, he said, even wish

for more. His seems to me to be a case for public patronage. Such patronage is not needed by eminent literary men or artists. A poet, a novelist, an historian, a painter, a sculptor, who stood in his own line as high as Owen stands among men of science, could never be in want except by his own fault. But the greatest natural philosopher may starve while his countrymen are boasting of his discoveries, and while foreign academies are begging for the honor of being allowed to add his name to their list." Owen was appointed to the position suggested — it was created for him — and the superb Natural History Museum in its present form is the result of that appointment.

From this time forth Owen threw himself with still greater ardor into the work of his life. He had all the riches of the museum to work upon, with teeming treasure sent to him from all lands for inspection, classification and description. He first taught naturalists to distinguish between analogy and homology. He first brought the torch of learning to bear upon the mysteries of parthenogenesis — that is, the reproduction of their kind by female types of life deriving their fertility from the ova from which they themselves are born. In a thousand directions he enlightened and taught his generation. He achieved many marvels of intelligent anticipation as the outcome of his own system. Perhaps his greatest triumph in this direction was his description of the extinct giant moa from the single leg-bone of the bird which was first sent him. The bone was as huge as that of a giant ox. But he declared it a remnant of a bird, and lived to have before him the entire skeleton of a moa, and to be photographed with it, holding in his hand a fragment of the bone from which he had described it.

Science was advanced a century through Owen's labors in elucidating the mystery of animal life past and present. Practically every learned body in Europe honored him, and the queen of England gave him for life the use of the charming Sheen Lodge, in Richmond Park, but Gladstone was taken by surprise when it was suggested that the great scientist should be knighted. Owen was nearly eighty at the time, and with all his modesty was not unwilling, simply for the sake of science, that the dignity should be his. "The chief satisfaction I should feel," he explained, "by such an instance of recognition would be in regard to the relation of my own to that of other countries in the estimate which has been allotted me." And he follows with a detail of services to the social life of the nation and to science generally which has probably no parallel. Owen died a knight, his death occurring at Sheen Lodge on December 18, 1802.

AMBROISE PARÉ

A Forerunner of Modern Surgery

AMBROISE PARÉ was born at Laval, in the department of Mayenne, France, in 1517. His experience, like that of so many surgeons in the past, was chiefly military. He saw much of war, and was surgeon to many kings.

In the treatment of wounds, Paré did something in the antiseptic direction, for he used turpentine, though little good can have come from the boiling oil which he employed at first. When his oil ran short on one occasion, he tried turpentine, and the results were so good that, as he tells us, he "resolved never more to burn thus cruelly poor men with gunshot wounds". Having estimated the antiseptic properties of turpentine today, and knowing what are the enemies of wounds, we can understand why the method thus forced upon Paré was so successful.

At Turin there was a surgeon who had a famous remedy for gunshot wounds. After two years of persuasion he consented to tell his formula, which was, says Paré, "to boil, in oil of lilies, young whelps just born, and earth-worms prepared with Venetian turpentine. Then was I joyful, and my heart made glad, that I had understood his remedy, which was like that which I had obtained by chance." So much for the earliest blind gropings for an antiseptic system of surgery. Yet when Paré had a compound fracture himself, white of egg, flour soot from the chimney and melted butter were applied to the wound of the greatest surgeon of the sixteenth century!

At the best, results were bad enough in those days. Paré declared that the King of Navarre's wound was certainly mortal, because a great joint was injured, and "all wounds of great joints are mortal". Today such joints are constantly opened, for the relief of local trifles, like a loosened cartilage in the knee-joint.

In 1561 Paré's great "Cinq Livres de Chirurgie" was published at Paris. These mark and make an epoch in the history of surgery. But the greatest of all his services to surgical science and practice was the introduction of the ligature. In his day, when limbs were amputated — this being the chief routine task of surgery in the days of constant war and ignorance of conservative methods of saving limbs — the bleeding from the cut arteries was arrested by means of a red-hot iron. They were cauterized, and so closed. Of course, there were no anesthetics in those days. Paré, merciful and original, who had already relieved "poor men" from torture with boiling oil, now daringly introduced the method of tying the arteries instead of burning them. To him we owe the ligature — *i.e.*, the piece of thread, silk, horsehair or catgut, by which arteries may be tied. We may faintly imagine what this was worth to soldiers, wounded in the quarrels of the "great", who would otherwise have had to face the red-hot iron. Finally, we have advanced from Paré's turpentine, so that wounds heal as they should, and ligatures do not break off, with renewed bleeding, as in the days when microbes were allowed to spoil the natural process of healing.

The "natural process", we say. Paré, with his prophetic vision, knew what he witnessed, and what was the real duty of the surgeon, a duty which, thanks largely to him, the surgeon of today can fully discharge. When praised for his success with a certain patient, he replied, "I dressed his wounds; God healed him".

AMBROISE PARÉ AT THE SIEGE OF METZ
From the painting by Chartran, at the Sorbonne, Paris.

This bold, humane, profound surgeon died in Paris in 1590.

LOUIS PASTEUR
The Founder of Preventive Medicine

LOUIS PASTEUR was born at Dôle, France, on December 27, 1822. The boy showed exceptional qualities, and was intended for an academic career in chemistry.

He studied at Besançon, and then in Paris, where he came under the influence of such great chemists of their day as Biot and Dumas, who thought highly of their young pupil. He earned his living, and obtained opportunities for research, in the usual fashion, by teaching in various universities, and he became professor of chemistry at the Sorbonne in 1867. From first to last, his was the chemical point of view, and students of chemical science rank him as an epoch-maker, just as the pathologist or the hygienist does. Indeed, so remarkable was his initial success in chemistry that his distinguished teachers deplored his attention to certain peculiar phenomena which were outside the domain of chemistry, and from which, they thought, nothing worthy of the ability of the young student could proceed. But modern medicine, surgery and hygiene thence proceeded.

Pasteur's first research revealed his quality. To him we may apply the old saying "He touched nothing that he did not adorn", if we substitute "elucidate" for "adorn". His genius for research, his intuition for the right course to proceed, and the right thing to look for, were simply supreme. A mere list of his successful researches — and all his researches were successful — would take many pages. First he found that there exists a living "microbe", to use his own term, which acts upon one variety of tartaric acid, but ignores another. The two differ only in one respect that we can discover. They form crystals identical in all respects save that one is "right-handed", and the other "left-handed". Rays of light, of the kind called "polarized", are twisted to right or left respectively by solutions of these varieties of the acid. The crystals and molecules of the two must have the same relation to one another as a right hand to a left, or any asymmetrical object to its image in a mirror. Hence we must think of molecules as *solid* things, with three dimensions in space; and we need a "stereo-chemistry" or "solid-chemistry" accordingly. This great science Pasteur thus founded.

But he was more interested, if possible, in the microbe that showed this singular preference for "right-handed" as against "left-handed" tartaric acid. This, he saw and said, was a case of specific fermentation, caused by a living organism. Hence, in due course, the long discussion between Liebig and Pasteur, the older man maintaining that fermentation is a chemical phenomenon, and the younger pointing to the *living* creatures from which it proceeds. We now know that both were right, for we can now extricate, from the living microbes found by Pasteur, the chemical ferments by means of which they work and live — as do all living things.

Pasteur quickly proceeded to show that other fermentations are due to microbes, besides that which proceeds in the salts of tartaric acid. The formation of lactic acid in sour milk is due to a microbe — there are now known to be many — which he found. He showed the same for butyric fermentation, and for the production of "vin-aigre", or vinegar, from wine, by means of the microbe he called the *bacillus aceticus*, and which ferments alcohol, forming acetic acid. The economic value of these researches was incalculable. They taught the wine manufacturers of France how to prevent wine disease. No one guessed then that diseases of somewhat more moment than those of wine might be involved in these researches also.

The silkworm is subject to a disease, which Pasteur was called upon to study. He did so, and found the parasite which preys upon the worm. Thus he saved the silk industry of France, and Huxley pointed out, long ago, that the value of Pasteur's work in such respects, quite apart from any services to man, had more than paid the whole indemnity of the Franco-Prussian War. Beer, like wine, is subject to disease, and Pasteur studied the minute forms of life which are responsible. About this time, also, he joined in the controversy on "spontaneous generation", and showed that, under certain conditions, life does not appear in vessels from which it has been excluded, and in which any preëxisting life has been destroyed by heat. This controversy was supposed to be closed at the time, but Dr. Charlton Bastian thought otherwise, and is now being justified. The

FRENCH APPRECIATION OF A BENEFACTOR OF THE HUMAN RACE THROUGH KNOWLEDGE

THE PUBLIC FUNERAL OF LOUIS PASTEUR—FROM THE PAINTING BY EDOUARD DETAILLE IN THE MUSÉE DE VERSAILLES

supreme value of Pasteur's researches was that they set him to the great task of seriously, and in detail, studying the behavior and properties of these microscopic forms of life.

He soon found their responsibility for fermentation in general, and passed from "diseases" of beer and wine, and from disease in the silkworm, to cholera in fowls. He was now approaching his fiftieth year, and was the greatest figure of the age in his own field. Yet, even so, his direct services to man were yet to come. Indeed, they occupy only the last chapter of his life, but it is a last chapter of which the words *Finis coronat opus* may truly be said. The responsibility of microbes for fermentation and putrefaction led Pasteur himself to use antiseptic and aseptic methods in his manipulations and experiments on animals. Lister applied the principle to man and created modern surgery.

Meanwhile Pasteur had proved that a certain microbe causes the terrible disease of animals called "anthrax". But this is also a disease of man, and here we have the first discovery that a human disease is due to a microbe. Pasteur proceeded with his researches, and showed how microbes can be modified in virulence, so that animals may be vaccinated with weak strains and protected against subsequent infection with virulent strains. This is exactly what Jenner had done for smallpox, without understanding the facts, many years before. Pasteur thus protected the flocks and herds from anthrax, performing a greater service than when he saved the silk industry.

But, with anthrax, he had reached man. He now tackled hydrophobia, and devised a method of curing this appalling disease by means of inoculation with "attenuated virus". He did not find the microbe of hydrophobia, and we still search for it. It is so minute that the microscope cannot reveal it, and even the ultra-microscope may not suffice.

To discuss adequately the work of Pasteur would be to deal with the monumental sciences of bacteriology, which he founded, and of public health, and preventive medicine, which he therefore founded, too, in their modern form. Space only avails to say that the French provided him with an Institute in 1886, and there he worked until his death. Here Roux, who helped to give us the antitoxin of diphtheria, and Metchnikoff continued his work. These, and a host of men all over the world, with Lister and Koch at their head, were the pupils of Pasteur. He died on September 28, 1895, and his remains lie in a chapel built for the purpose under the Pasteur Institute, where his work is carried on.

Louis Pasteur is the greatest physical benefactor of man in recorded time. His work has already changed the conditions of human life and the very face of civilization, and has enabled mankind to begin the conquest of the "Dark Continent", hitherto held by microscopic parasites and the insects which convey them. Pasteur was a devout Catholic; his favorite motto was "*Il faut travailler*", and he lived it all his life. His favorite expression in philosophy was "*Tout est miracle*"; and his genius was one of its clearest justifications.

WALTER REED

Who Proved that the Mosquito Carried Yellow Fever

WALTER REED, American bacteriologist and army surgeon, was born in Gloucester County, Virginia, September 13, 1851. After attending the University of Virginia he took his medical degree at University Medical College, New York, and in 1875 was appointed assistant surgeon in the army. For the year 1890 he was stationed in Baltimore and during that time studied bacteriology under Dr. William H. Welch of Johns Hopkins Hospital, the famous teacher of many eminent men. Three years later, he himself gave instruction in bacteriology to the young officers of the Army Medical School, when he was acting as curator in the Army Medical Museum at Washington. He established a laboratory there and did some brilliant research work himself, so that in 1898 he was at the head of the board (with Dr. Victor C. Vaughan and Dr. Edward O. Shakespeare) appointed to investigate the epidemics of typhoid occurring among the United States troops at the beginning of the Spanish-American War.

In 1900 with the occupation of Cuba by the United States, need arose for the establishment of sanitary conditions suitable for Americans to live in. Disease was prevalent, especially yellow fever, and Havana itself in a woefully unsanitary condition, the streets unswept, garbage piled in heaps, while the sewerage system was hardly more than a name. A commission was appointed with Dr. Reed as chairman to investigate Sanarelli's organism, which was at that time quite generally believed to be the organism which caused yellow fever. Dr. Reed and his workers proved that the infection was carried from man to man by the *stegomyia* variety of mosquitoes, which had become infected by previously biting persons sick of yellow fever. The commission did its work with great thoroughness and devotion, and in 1902 the city was handed to the new republic in a wonderfully improved condition. A well-regulated system of street cleaning and garbage collection was put in operation. Many of the streets were repaved, and various kinds of experimental pavements were laid. Contracts were let for a new sewer system, and a complete survey of the city with a view to adopting a system of street grades was made. Hospitals and other buildings were so thoroughly disinfected that yellow fever, which during the war had carried off thousands of people, had been wholly stamped out. At its successful conclusion Reed returned to Washington where he became professor of bacteriology in the Army Medical School, and of pathology and bacteriology at Columbia.

He died on November 22, 1902, after an operation for appendicitis and was buried at Arlington. In 1893 he had been promoted first on the list of majors of the Medical Department of the United States Army, and the Secretary of War had recommended to Congress his promotion by a special act to the rank of colonel.

SIR RONALD ROSS

The Ender of the Malaria Mosquito

MAJOR SIR RONALD ROSS, K. C. B., the son of General Sir C. C. G. Ross, K. C. B., was born on May 13, 1857. Educated at St. Bartholomew's Hospital, London, he entered in 1881 the Indian Medical Service, and spent seven years wandering from Madras to Bangalore, from Burma to the Andaman Islands. His interest in the problem of malaria was aroused through finding that from half to a quarter of the total sickness in many tropical countries was caused by it, the natives of India being killed or permanently weakened in enormous numbers by the malady, and he resolved to devote his life to the conquest of this world-wide plague.

During leave in England in 1889, he studied bacteriology with a view to investigating the cause of the disease. But the laborious researches he made on returning to India did not bring him much nearer his goal. A Frenchman, Laveran, had discovered the malaria parasite in Algeria, in 1880, but the young British surgeon was not well acquainted with Laveran's work. During a visit to England, however, in 1894, he met Sir Patrick Manson, who had gone into the matter, and discussed with Ross the Frenchman's theory that mosquitoes were the carriers of the disease.

When back in India, Ross took up the study of mosquitoes — a practically new ground in science — and found that little was recorded about their structure and habits. In May, 1895, he fed two kinds of gnats on patients suffering from malaria, and discovered the parasites in the blood of the insects. In August, 1896, the assistant-surgeon of the civil hospital at Bangalore bravely submitted to a dangerous experiment. The two kinds of gnats that Sir Ronald had been studying were allowed to feed on malaria patients, and then bite him a few days later, when the parasites should have developed. There was, however, no result.

His repeated failures convinced Ross that he had been working with the wrong kind of mosquitoes. In April, 1897, he went to an intensely malarious district in the Nilgiri Mountains, to see if he could discover another likely kind. There, for the first time, he saw an anopheline mosquito, which is the true carrier of malaria — the other kind of gnats he first experimented with being responsible for yellow fever, and perhaps other maladies. On August 20 Sir Ronald

traced the malaria parasite in two large, dappled-winged mosquitoes, which he had bred from the larva stage, and fed on a case containing infected food. This observation gave him the clue to all that followed, because it indicated the position of the parasite in the mosquito, and also the variety of mosquitoes capable of carrying it. The problem was practically solved, and only details and formal proofs needed.

Sir Ronald did not succeed in winning fame and influence in India by one of the greatest discoveries in the history of medicine. No real attempt was made for some years to prevent malaria in Calcutta and other important cities there by the methods he had worked out. Happily, the world outside India soon recognized the importance of his discovery, and in 1899 he was appointed director of the newly established School of Tropical Medicine in Liverpool, and in 1913 physician for tropical diseases at King's College Hospital, London. In 1902 he was awarded the Nobel Prize for medicine, and during the Great War he was consulting physician to the Indian troops.

JOHN TORREY

One-time Chief of American Botanists

SEVENTY or eighty years ago, a new evergreen tree was discovered in the South, which it was at once determined should bear the name of the one-time chief of American botanists, John Torrey. Shortly after a congener was found in California. Another species had already been recognized in Japan, and about thirty years after a fourth in the mountains of northern China. So that, all round the world, *Torreya taxifolia*, *Torreya Californica*, *Torreya nucifera*, and *Torreya grandis* — as well as his own important contributions to botany — keep the naturalist's memory as green as their own perpetual verdure.

John Torrey was born in New York, August 15, 1796, and received such education only as the public schools of his native city then afforded, together with one year's residence in a school in Boston. When he was fifteen or sixteen years old his father was appointed fiscal agent of the state prison at Greenwich, N.Y., then a suburban village, to which the family removed. While in his teens Torrey came under the influence of that famous teacher of science, Amos Eaton, who explained to him the structure of flowers and kindled a zeal for botany which lasted to the end of his pupil's life. This interest in natural science soon extended to mineralogy and chemistry, and probably determined his choice of a profession. In 1815 he entered the office of Dr. Wright Post, in New York, where it was his duty to prepare the various powders, tinctures, etc., and put up the prescriptions for the patients: he was at the same time studying at the College of Physicians and Surgeons, and in 1818 took his M.D. degree. For a while he practised medicine — with but indifferent success and liking, spending his abundant leisure in botanical studies. In 1824 he gave up medicine and entered upon the duties of professor of chemistry in the United States Military Academy at West Point. Thereafter up to the day of his death, he found his remunerative occupation as a chemist, either teaching chemistry or in some position to which his profound chemical knowledge adapted him. While yet a medical student, Torrey reported to the Lyceum of Natural History — of which he was one of the founders — his "Catalogue of the Plants growing spontaneously within Thirty Miles of the City of New York", and two years later it was published. "When we consider the youth of the author, barely twenty-one, we must regard this catalogue as a remarkable performance. Only those who have undertaken similar works can appreciate the amount of labor necessary to its production, and botanists who go over the same ground at the present day wonder at the completeness of the list. It gives us some idea of the astonishing growth of New York to read in this catalogue of some of the author's favorite localities, such as 'Love Lane', 'Bogs near Greenwich', and 'Swamp behind the Botanic Garden', and places that have long been covered by paved streets and brick and brown-stone blocks."

Elliot's sketch of the Botany of South Carolina and Georgia was at this time in the course of publication, and Torrey planned "A Flora of the Northern and Middle United States", as a counterpart.

It was published in numbers, but only one volume was completed, and today it is exceedingly rare. The book contains over five hundred pages, and includes the first twelve classes of the Linnæan system. Torrey was not backward in perceiving that this system must be superseded by the natural system of Jussieu, and it was partly on this account that he abandoned the undertaking, and followed up his conversion by publishing in 1826 a description of the collections of Dr. Edwin James, the botanist of Major Long's expedition in 1820. This expedition skirted the Rocky Mountains and Dr. James, first and alone, reached the beautiful alpine vegetation. Torrey's treatise is the earliest of the sort in this country, arranged on the natural system; and with it begins the history of the botany of the Rocky Mountains, if we except a few plants collected early in the century by Lewis and Clarke, which are recorded in Pursh's "Flora".

In 1838 "The Flora of North America" by John Torrey and Asa Gray was first published in numbers, at irregular intervals which continued until 1843, when the government began to explore the western territories, and such wealth of new flora was revealed in the collections brought home as needed all the botanists' time, and new plants poured in year by year in such numbers as to overtask their powers, weighted as both of them were with professional engagements. The results are a long series of important contributions to the government reports of the western country; from that of Long's in which Torrey first developed his powers through those of Nicollet, Frémont, Emory, Sitgreaves, Stansbury and Marcy, down to that of the Mexican Boundary.

In the midst of these labors, and at the same time discharging professional duties at the College of Physicians and Surgeons and at Princeton, when the New York State Geological Survey of 1836 was organized, Torrey was appointed state botanist and prepared for the survey "The Flora of the State of New York". In 1857 he exchanged a portion, and a few years later the whole, of his professional duties for the office of United States Assayer, and calls upon his time became even more numerous and urgent. Speaking of this office, his pupil and associate, Asa Gray (in a memoir read before the American Academy of Arts and Sciences in 1873), said, "In addition to the ordinary duties of his office, he was frequently requested by the head of the Treasury Department to undertake the solution of difficult problems, especially those relating to counterfeiting, or to take charge of some delicate or confidential commission", and twice these commissions gave him opportunity to recruit failing health and to gather floral treasures, when he was sent to California by way of the Isthmus, and "enjoyed the rare pleasure of viewing in their native soil, and plucking with his own hands, many a flower which he had himself named and described from dried specimens in the herbarium, and in which he felt a kind of paternal interest".

In 1861 he gave his valuable collection and botanical library to Columbia College, where he was professor of chemistry at the time of his death, and spent many weeks and months in putting this — in some respects — the most important herbarium in the country in proper condition for study and reference.

His last botanical work was done on the manuscript of a report on the plants collected along the Pacific Coast in Admiral Wilkes's expedition. But his strength was unequal to the task. In the winter of 1872–73 he had a severe attack of pneumonia, from which he could not rally, and he died suddenly in the spring of the latter year.

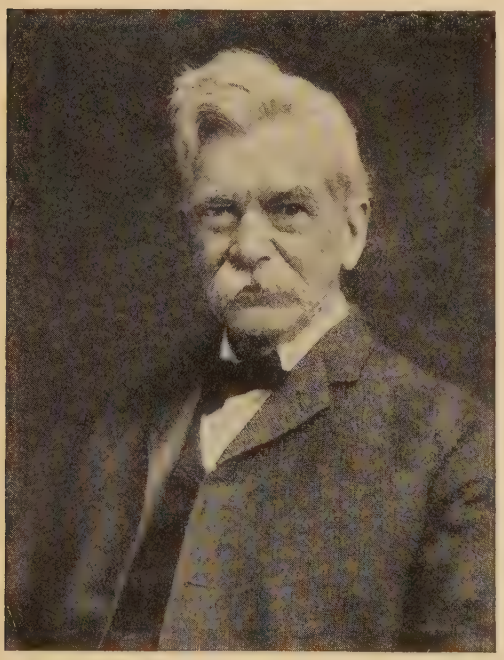
ADDISON EMERY VERRILL

Distinguished American Zoölogist

PROFESSOR VERRILL was born at Greenwood, Oxford County, Maine, on February 9, 1839. He was a student and assistant of Prof. Louis Agassiz and obtained his degree of B.S. at Harvard in 1862 (hon. A.M., Yale, 1867) and, from 1864 until his retirement in 1907, occupied a chair of zoölogy and geology at Yale. He was also professor of comparative anatomy and entomology in the University of Wisconsin from 1868 to 1870, curator of

the Boston Society of Natural History from 1864 to 1874, and president of the Connecticut Academy of Science for many years. He was associate editor of *The American Journal of Science* from 1869; an active member of the National Academy of Science from 1872, and a member of many other American and foreign societies. From 1880 to 1887 he was in charge of the deep-sea dredging expeditions of the United States Fish Commission.

From 1860 Professor Verrill carried on many original and valuable investigations in relation to the marine invertebrates of



ADDISON VERRILL

the entire Atlantic and Pacific coasts of North and Central America with especial reference to the corals, annelids, echinoderms and molluscs; and on the marine fauna of Bermuda, the West Indies, Panama and Brazil. He was the first to describe and classify the giant squids of the North Atlantic and became the leading authority on living cephalopods. He wrote over 350 papers on zoölogical and geological subjects, describing hundreds of new species and genera and his "Report upon the Invertebrate Animals of Vineyard Sound and Adjacent Waters" (with S. I. Smith, 1874) is a standard manual of the marine zoölogy of southern New England. He is also the author of several monographs on the zoölogy, geology and paleontology of the Bermudas, as well as a popular work "The Bermuda Islands", and in company with his students made two exhaustive scientific expeditions to those islands. Among his more recent works are a monograph of the starfishes of the Pacific Coast of North America in two volumes with 109 plates; a report on the Atlantic Coast starfishes with 29 plates (1915); a report on the Alcyonaria of the West Indies; monographs on the reef corals of the West Indies and Brazil; monographs on the Actinozoa of the Atlantic, etc. His extensive collections of invertebrates are deposited in the museum of Yale University.

Professor Verrill's son, Alpheus Hyatt (born July 23, 1871), is a well-known author and a contributor on natural science to various periodicals and has written many descriptive travel books, especially relating to the West Indies and South America, where he resided for a number of years. He is also the author of numerous works of fiction and of practical handbooks on the gas engine, aviation and radio on which subjects he is an authority, while his books on the New England whaling industry are considered standards. As an artist he has illustrated numerous scientific works, Webster's Dictionary, the Clarendon Dictionary and his own books and articles. He was the first to successfully photograph living marine invertebrates under water and living insects, and is the originator of the Autochrome process of photography in natural colors. He conducted various scientific expeditions to the Bermudas, the West Indies and tropical America, and rediscovered the supposedly extinct Solenodon Paradoxus in Santo Domingo in 1907. For several years he was engaged in exploring the unknown interior of British Guiana and in making collections for the Museum of the American Indian in New York City, and visited many hitherto unknown Indian tribes. He also carried on similar explorations among the primitive Indians of Panama, studying tribes and penetrating districts never before visited by white men.

INCOME DEMANDS UPON MODERN HOUSEKEEPING

HOW TO MAKE BOTH ENDS MEET

SCIENCE is fast meeting the new problems of the modern home in respect to changing family life. There are new theories for the training of children, new facts as a guide in feeding the family, new procedures for income budgeting and spending, changed industrial opportunities, and improved household arts.

The economic estimate of a woman's time has a new valuation since she is more and more entering the industrial and professional world. It has been necessary to have a better control of the technique of housekeeping in order to free the time of household workers for new demands on their time and to make more desirable homes on available incomes. Consequently we have better working equipment with a lessened and more economical floor plan; a studied work schedule; an analysis of the housekeeping job, as in other industries, to make an economical use of time and a study of the causes of fatigue as a recognition of the value of the worker's strength. The whole trend is to discover how to reduce the demands of the physical plant and how to increase the efficiency of the family; how to run a home with available income in order to insure business and family security.

Approximately one-fifth of the population is engaged in the business of homemaking, while the entire population is concerned with its results. No single activity engages the time and services of so many people as do those activities connected with the acquirement of food, clothing and housing. These have a world-wide source, with an investment estimated at fifty billion dollars.

It is a situation which demands harmonious adjustments, for only under a sane economic regime can families keep a good standard of living with the present level of incomes. The great majority of people are trying to live on less than $2,000 a year. Their concern is not alone to have more dollars, but to learn how to make what they buy with their dollars produce a larger satisfaction.

Now success in the manner of spending the family income consists very largely in a demand for those things which will give more buying power for the future. It often means an investment in health and education, rather than in larger houses and more clothing—anything to increase family efficiency. Or satisfaction is attained when an efficient living is secured, and the increase goes to savings and advancement. This may be accomplished by a more simplified taste; by a lessening of waste of labor, materials and money; by a better practice of business methods in household expenditures; by a saner demand upon the producer, by which cost of production is lessened. It cannot but be that the next step in household life is a more rational and intelligent consumption of goods whereby the standard of living does not rise faster than the income increases.

That there is opportunity for good housekeeping to affect human welfare is shown by the fact that somewhere about thirty to forty per cent of the population is living at the expense of the remainder; thus lifting them out of the class who at least pay their way in life. It makes expensive production to care for them.

Household commodities will be produced at less cost when sane demand helps the producer to lessen the expense of distribution and there is less scrapping of machinery because of fitful demand caused by changing styles and change in fabric.

We are advised to find our taxes in overcoming the estimated ten billion dollars which is being wasted in industry. There are automobiles and gasoline and houses and food for more people than now own them, as well as taxes, in the amount of this waste, providing demand is trained and waste eliminated.

In addition to the economic adjustments to be made in the world's housekeeping, there is convincing evidence of the need of trained housekeepers to protect the health interests of the family and the state. Intelligent homemaking has meant a higher average of health among children and adults. This is shown in the decreasing number of underweight and malnourished children; in the larger control of disease and the lessened number of dietary disorders. Human capital is conserved according to the amount of intelligence shown in the accepted, improved methods of living.

It is recognized that the utilization of foods by the human family is somewhat like that of drugs in medical practice. Science has revealed facts about food and nutrition important for longevity and efficient living.

Our social approach to home problems is a measure of family development. The clothing and housing problems of the family may be a hindrance to family recreation, enjoyment of music, public enterprises and reading.

The present-day responsibility is to look beyond the article of clothing purchased to the welfare of the producer, as well as to be concerned with the manufacturer's label as being a guarantee to standardized fabrics, fast colors and good workmanship. The rapid changes and extremes in fashion mean money diverted from constructive investments of time and capital.

Houses now in existence were designed for families under different social conditions. The family will not adjust its life to the house of early construction, when there was more domestic labor, but finds it desirable to build and modify the house to present-day prevailing incomes and social demands. The homemaker has to learn how to make the home a retreat and protection, and still adjust to the subsidizing by community forces of the family's recreation, eating, courting and educating.

Available incomes spent with care secure for some a very bare existence, for others some comforts, while some are able to indulge in luxuries. A higher standard of living and power of example have frequently transferred luxuries into the class of necessities, in order to ward off disagreeable experiences. The establishment of a home may be a financial embarrassment, then, unless there is an accomplishment, by skill and training, by which our wants are supplied at a lessened expense. To that end education for homemaking, called in our schools Home Economics, is aimed, not only to increase the efficiency of the wage-earner in order that he may add to his income, but to make his dollars buy more after they are earned.

ECONOMIZING A WOMAN'S TIME

A MODEL "SEWING CENTER" FOR ECONOMIZING TIME AND EFFORT

A woman making an apron in the usual manner with tools and implements in various rooms of the house walked 689 feet. Using this sewing center she walked only 62 feet. (From the work of Miss E. M. Cushman, Cornell University.)

THE LAUNCHING OF THE S-47, ONE OF OUR LATEST SUBMARINES

Photo Kadel & Herbert

This striking revelation of the bow and underbody of the latest type of U. S. Navy submarine was caught as the S-47 took to the water at the Fore River Yard of the Bethlehem Shipbuilding Corporation. She is the last of a program of six, has a cruising radius of 8000 miles and a speed of fourteen knots on the surface.

SUBMARINES AND TORPEDOES

The Story of Their Invention, Construction, Improvement and Use

RECENT WONDERS OF UNDER SEA NAVIGATION

WHEN the progenitors of the human race emerged from the waters to conquer the earth, they sacrificed the mastery of the deep. Man is practically the only mammal incapable of swimming naturally. For thousands upon thousands of years he has been seeking to regain not, indeed, identically the powers he has surrendered in relation to the waters, for he does not covet a return of gills and swim-bladder, but of such means as shall enable him to regard the sea as a highway rather than as a barrier, as a helpful medium of travel, instead of interposing menacing bounds which he may not pass. Long before the dawn of history he learned to sail the seas. He was a mariner before he was a scholar, an adventurous navigator before compasses were fashioned or natural laws understood. He began his contest with the elements without reckoning their nature, or troubling to codify laws for their control. He learned to swim and to sail and steer a raft by intuition as wonderful as that by which Archimedes, in his flooded bathroom grasped the secret of specific gravity. Long before Archimedes wrote his immortal treatise upon the pressure exerted by water, untutored men had been accustomed to test and try the matter in actual practice without a rule to guide them. They had not only made themselves mariners; they were by way of becoming sub-mariners.

This greatest of all the conquests won at sea — the power to float, inclosed and safeguarded, beneath the surface of the water, a feat which has become really practicable only within the last decade or so — this conquest was gained in part by the ancients before the mighty genius of Archimedes illumined the world. Aristotle, a century earlier, had made it clear that in his day the idea of submarine locomotion had possessed the mind of his contemporaries. He writes of a submarine vessel which he declares to have been employed at the siege of Tyre; and of an air-tube, like the trunk of an elephant, by means of which divers drew air-supplies from above the surface of the water. Alexander the Great is stated to have made use in warfare of the services of men who were equipped with a contrivance that enabled them to walk at the bottom of the sea; while Pliny preserves record of a diving apparatus. Thus, during four centuries leading up to the Christian era, men, having grasped the secret of riding the waves, were seeking, more or less successfully, to tunnel them, as it were. We find no trace of the idea for another thirteen centuries, when Roger Bacon, by his allusion to the air-tubes used by divers, shows that the plan for breathing and moving beneath the water, if it had been lost, had come again into being. The originality of idea and the courage to put the plan to the proof were there; only the means were lacking. These pioneers risked no more than the gallant fellows of our navy of today, for a man has but one life to lose, but they risked as much.

For we have ample record of submarine experiments which proceeded beyond plan and model to actual service in the water. We might demand better evidence in a court of law than that of the good

Bishop Claus Magnus, who states that certain pirates of his time made use of leather vessels, "for the purpose of going wherever they wish, either above or below water." Although he states that "In 1505 I saw two of these leather boats or skiffs in the Cathedral Church of Aslöe, in the western porch", we have no testimony as to how these performed their diving feats. It seems a fact, however, that in 1538 a diving-vessel was exhibited at Toledo before the Emperor Charles V, and that, twenty years later, the Venetians made use of some form of submersible boat to raise a sunken galleon. Another twenty years elapse, and we have a note of the plan of William Bourne, one of Queen Elizabeth's naval gunners, who projects a vessel "that may go under the water unto the bottom, and so come up again at your pleasure." The vessel was to contain three compartments, one above another, the upper and lowermost water-tight, the middle one pierced with holes and provided with two longitudinal bulkheads, which latter, when drawn inward, admitted water, and caused the boat to sink, but which, when pushed out hard against the perforated sides, expelled and excluded the water, so enabling the vessel to rise.

James II is said to have encouraged a certain Dutchman, Cornelius Drebble, to make a submersible boat, which boat is declared to have dived in the Thames, carrying "12 rowers besides passengers." A warrant is extant, dated 1626, from "His Majestie to the Master of the Ordnuance, for the makyng of dyvers water mines, water petards, fforged cases to be shot with fireworks, and boates to goe under water." And one of the following year to the Duke of Buckingham for the delivery of "360 fforged iron cases with fireworks, 50 water mynes, 290 water petards, and two boates to conduct them under water for H.M. present services to goe with the fleete."

Thus century after century the idea persisted. Men were determined to emulate the fishes. Steam-power was unknown, so they had recourse to manual labor, working their craft by means of oars and an anticipation of the screw propeller, which it took many years to render acceptable to the builders of ships for ordinary ocean transport. David Bushnell, an American, was the first of whose exploits in modern warfare we have any clear trace. He invented a small vessel to carry one man, which could be submerged, worked with an oar and steered by a primitive rudder. He very nearly succeeded in 1776 in torpedoing a British man-of-war. He got beneath her, but had not strength or skill enough to affix his explosive, which drifted clear, and, answering its time-fuse, burst an hour late, well away from its intended victim.

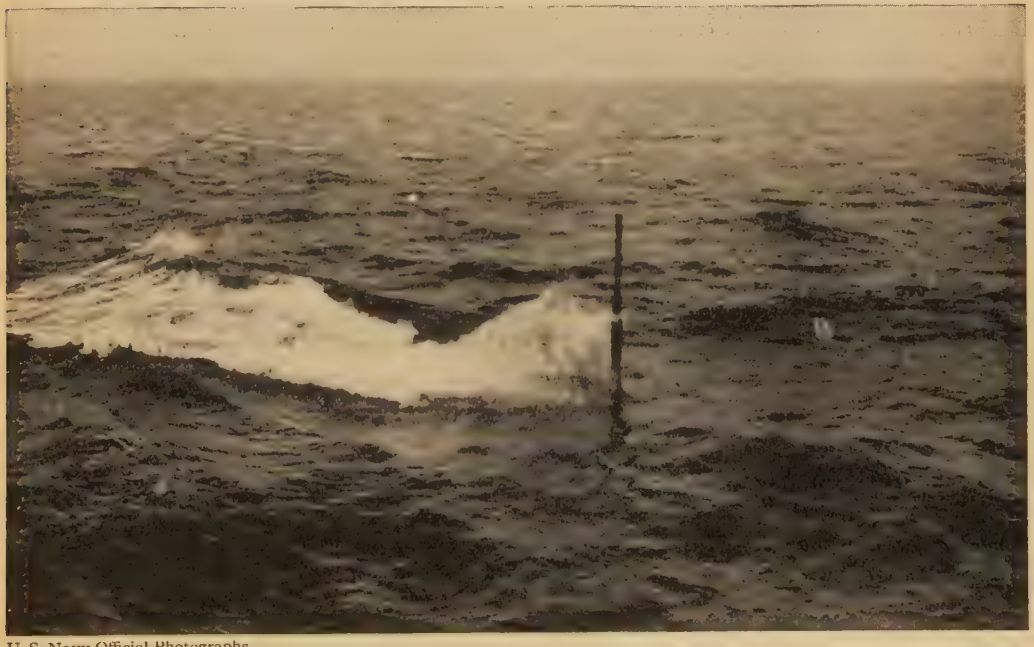
Robert Fulton, of steamship fame, was the next prominent worker in the field. His experiments were carried on in France, with the knowledge of Napoleon. Strange that the wonderful mind of that remarkable man never grasped the potentialities of either the steamboat or the submarine. Had Fulton succeeded in converting him, Napoleon might have known no defeat at the Nile or Trafalgar; and Waterloo, if ever fought, might have had a different issue. He thought at one time, after his final defeat, of escaping from France to America, it will be remembered; and a submarine was actually built in the United States, with a view to rescuing him from St. Helena, but it never set sail.

Fulton's boat, which was exhibited with success, furnished the outline that has been more or less closely followed for submarines. It was cigar-shaped, carried a small conning-tower, and was steered by a rudder. Propelled by hand, it was fitted with a mast for use on the surface, and, carrying air at high pressure, he was able to remain for several hours under water in the vessel, and to torpedo sunken craft. But the time was not ripe for the acceptance of the invention, and Fulton turned to more profitable work. A German inventor, Bauer, who received the patronage of the Prince Consort in England half a century later, was not more successful, nor was a Frenchman, whose vessel was launched at Rochefort and propelled by compressed air. It was not until our Civil War that any real success was attained.

U. S. SUBMARINE S-49 MANŒUVERING

FULL SPEED ON THE SURFACE

RUNNING AWASH



U. S. Navy Official Photographs

RUNNING SUBMERGED

In 1864 the submarine became a practical factor in war when the Federal frigate "Housatonic" was torpedoed and sunk off Charleston by a Confederate submarine boat. Never before had such a thing happened, and, only in the present war has such a feat been repeated. Then, however, the successful boat carried its torpedo upon a spar, and the explosion was as dangerous to the attacking side as to the attacked. It was not until the torpedo proper attained a higher state of perfection that the idea of the submarine again became seriously considered. Then it was intended that torpedo-boats should be submarines. And so we come to the history of our own times, with the rival schemes of Holland in America and Nordenfelt in Europe.

A TRAIL OF DEATH FROM A SUBMARINE

The submarine is seen rising to the surface to note the effect of the torpedo it has just discharged. Its track towards its objective is marked by the rising bubbles of compressed air.

It will be convenient to pause at this point to consider for a moment the mechanism of this torpedo which called the submarine vessel of war into being. It is in its latest form essentially a huge automobile contact bomb, twenty-one inches in diameter and over twenty feet in length, costing thousands of dollars, comprising within its interior some of the highest refinements of mechanical contrivance, and capable of sinking a ship on which several million dollars may have been spent.

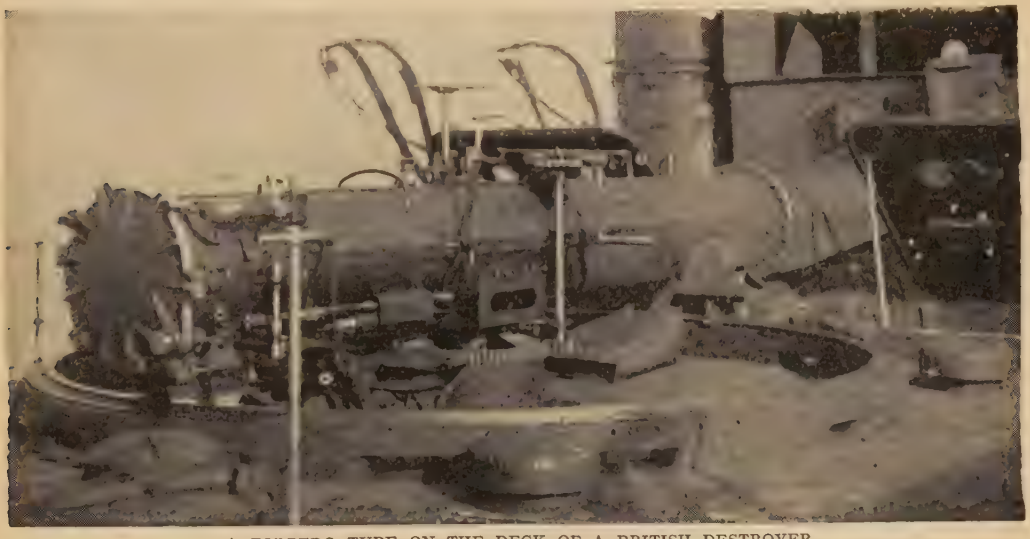
The torpedo was cradled in the cumbersome explosives which Bushnell and Fulton fired so long ago beneath the water. Those, if successful, would have been as effective as the newest torpedo, with this difference: the new explosive is sent unattended upon its errand; the old had to be taken to its victim. The idea lay dormant after Fulton's day until the Civil War. Then it was revived. Primitive torpedoes were rigged up on spars projecting from small vessels, and upon being brought in contact with the object of attack were exploded by means of an electric battery. Often the aggressors perished with the assailed, but no fewer than thirty-four vessels were blown up by torpedoes during that war. Nothing further happened, however, until an Englishman, Robert Whitehead (1826–1905), settled at Fiume, and evolved from the unworkable scheme of an Austrian captain, the Whitehead torpedo so widely used, especially by the British Navy.

In the United States Navy the American Bliss-Leavitt has now largely superseded the Whitehead torpedo, and we may with profit glance briefly at its principal modern features. It consists of a steel tube, cylindrical for most of its length, slightly rounded at the forward end, and tapering at the rear end, divided internally by steel bulkheads into a succession of watertight compartments. At the front end is the war-head, containing 200 pounds of guncotton, and also the mechanical firing arrangement. The latter consists of a rod, which on contact with any resisting substance, is driven in upon a detonator which fires a primer, thus exploding the charge of guncotton.

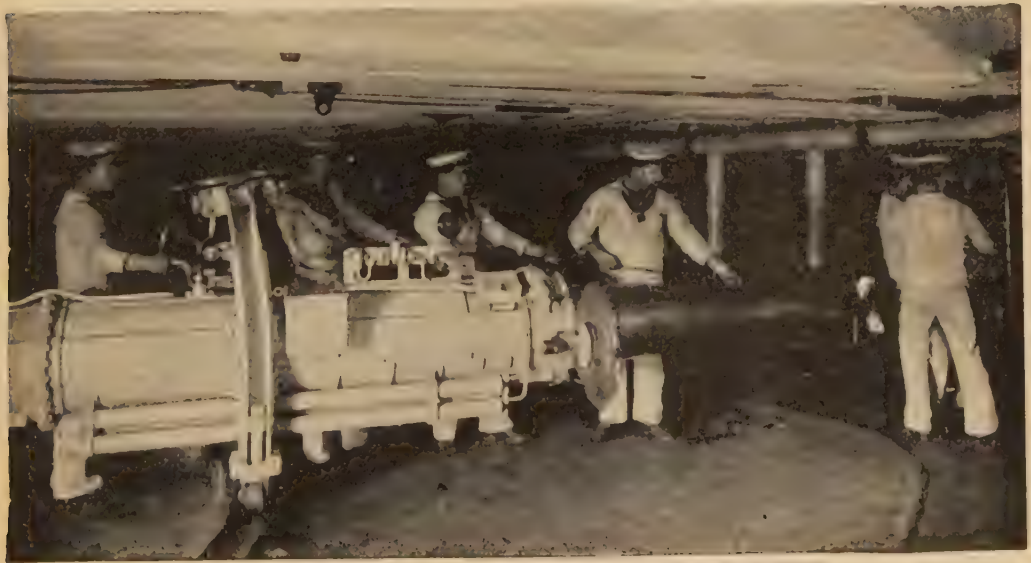
THE BRITISH NAVAL TORPEDO

PICTURE-DIAGRAM OF THE STRUCTURE OF THE WHITEHEAD TORPEDO

1, Twin screws revolving in opposite directions; 2, vertical rudder; 3, horizontal rudder; 4, bevel gear; 5, propeller shaft; 6, buoyancy chamber; 7, starting gear, the engines of which are set off automatically as the torpedo leaves the tube; 8, starting pin; 9, engine chamber; 10, balance chamber; 11, gyroscope; 12, a weight which controls the depth of running by acting on the horizontal rudder; 13, compressed air chamber; 14, war-head; 15, guncotton charge; 16, primer of fulminate of mercury; 17, striker, which, driven in, fires the charge; 18, safety-pin, withdrawn at the moment of firing; 19, fan revolving in the water to unscrew and free the striker.



A TORPEDO TUBE ON THE DECK OF A BRITISH DESTROYER



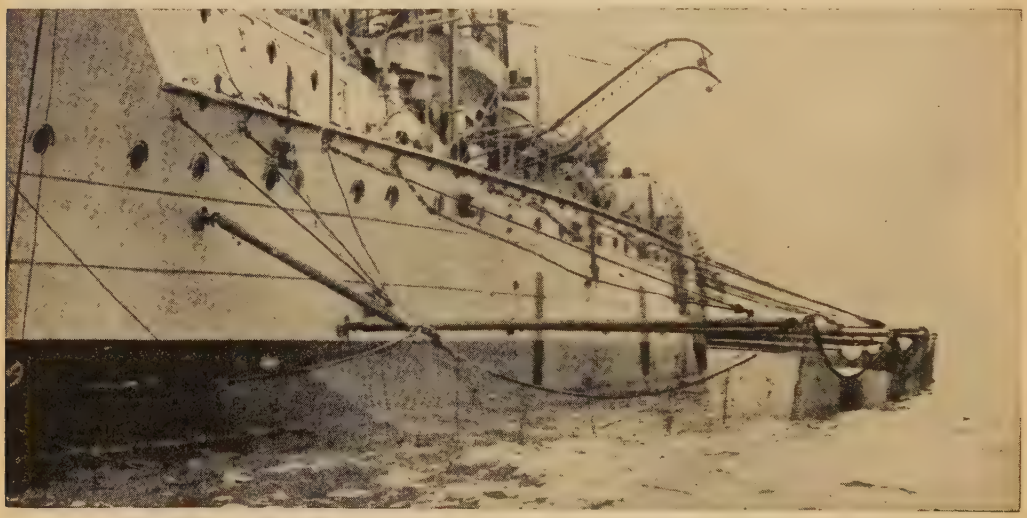
RUNNING A TORPEDO INTO THE TUBE ON A BRITISH WARSHIP

Behind the war-head is a buoyancy chamber, and next is the air-chamber in which air compressed to a pressure of over 2000 pounds to the square inch is stored. This chamber is practically the boiler room of the torpedo, and furnishes the motive power for the powerful balanced Curtis turbine which drives the torpedo through the water. This turbine weighs less than 50 pounds but can develop about 125 horsepower. In order to gain still more power than was originally obtainable the compressed air is heated as it passes from the air-chamber to the turbine engine, by means of a superheater that uses alcohol as a fuel, the alcohol being stored in a flask just behind the air-chamber. By this device the speed and range of the torpedo has been very much increased.

In the next compartment is the Curtis turbine engine introduced by Mr. F. M. Leavitt. This engine consists of two turbine-wheels turning in opposite directions, and driven by the superheated compressed air at a speed of about 10,000 revolutions per minute. The propeller shafts do not turn at this speed, however, but are geared down by means of reduction gears just back of the turbine to a speed of about 1500 revolutions per minute. This turbine has taken the place of the 3 or 4-cylinder reciprocating Brotherhood engine installed in earlier torpedoes, and constitutes a marked improvement.

In order to make the torpedo run at a certain depth an automatic depth gear is necessary. This consists of a flexible diaphragm exposed to the pressure of the water, and held in position by a spring. A slight change in pressure causes this diaphragm to act upon a system of levers which move the horizontal rudders at the tail of the torpedo just enough to keep the torpedo at a certain depth. A pendulum added to the mechanism also acts on the rudders if the inclination of the torpedo exceeds three or four degrees.

The steering arrangements which keep the torpedo on any desired course after it has been discharged from the tube, are controlled by a gyroscope placed in the compartment aft of the engine. The gyroscope is a small but heavy flywheel mounted in a pivoted frame, now used for steering ships and stabilizing ships, and airplanes. It is started spinning by means of a small turbine operated by compressed air, but is later released, and then spins alone. A recent patent, however, spins the wheel continuously by electricity. Since the gyroscope has the peculiar property of retaining any position given to it, any movement of the torpedo to the right or left causes an air-valve connected to the frame of the gyroscope to operate the servo-motor, a small cylinder and piston connected to the vertical rudders of the torpedo.



THE WIRE NETS HUNG ON BOOMS AROUND A WARSHIP TO CATCH TORPEDOES

At the tail of the torpedo are placed the two propellers, revolving in opposite directions so as to keep the torpedo from turning over and over in the water; the vertical and horizontal rudders already spoken of; and the fins for steadying it. Other devices are used as safeguards, for instance, to prevent the missile from becoming effective until it has passed a certain distance from the vessel; another prevents the loss of the torpedo in case it fails to explode. Some torpedoes have also been provided with net-cutting devices. The United States now has torpedoes 21 inches in diameter and about 21 feet long. These have the surprising speed of 45 miles an hour and a range of 10,000 yards, or nearly six miles.

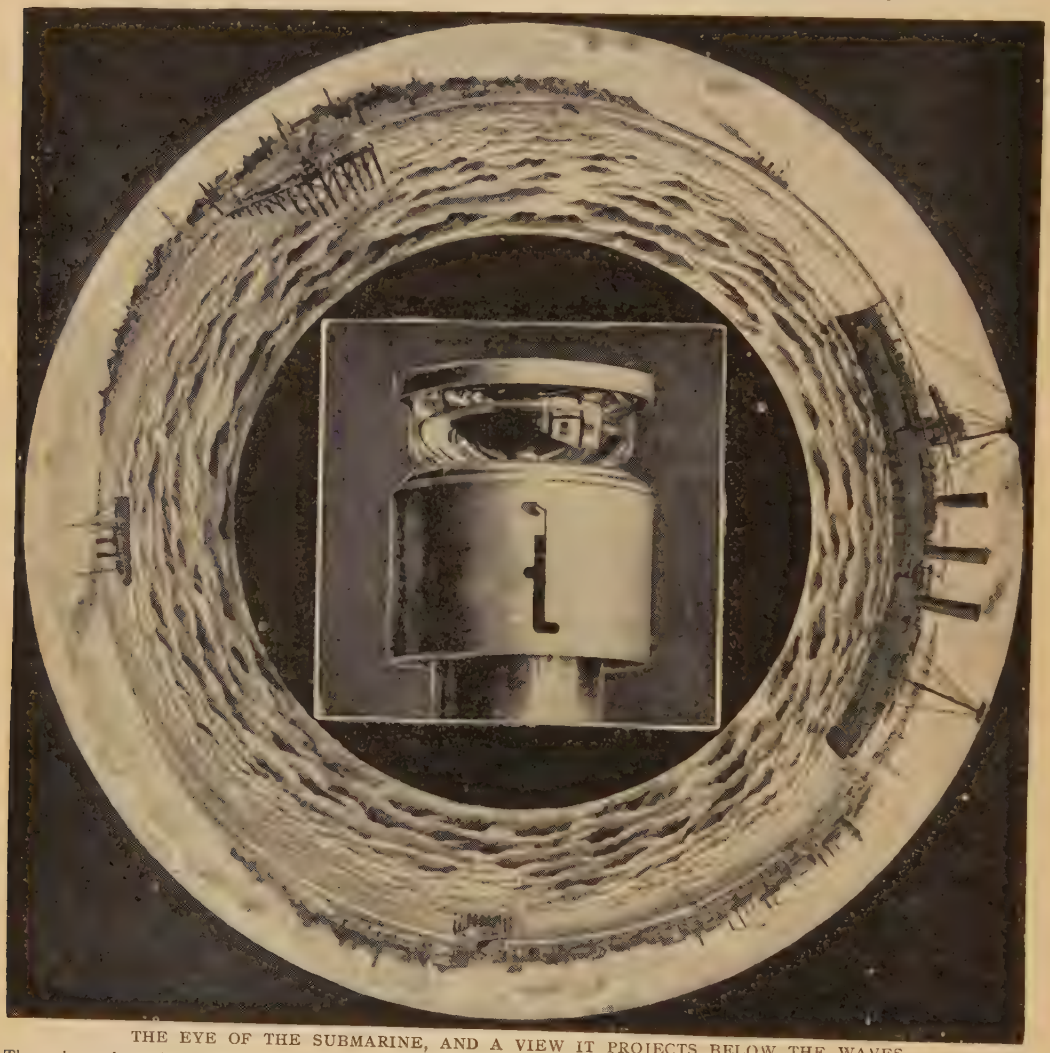
The Brennan torpedo is not unlike the Whitehead in general features, but it is driven by an engine on shore. This torpedo carries in its interior two drums of fine piano-wire, the ends of which are connected to the two drums of the shore engine. The revolutions of the engine-drums cause the wire in the torpedo rapidly to unwind. The revolving reels cause the screw propellers of the torpedo, in turn, to revolve, so driving the missile on its way. Steering is perfectly controlled by the wires, which actuate vertical rudders. Accelerating the speed of one drum causes the connected propeller to turn the faster, so altering the direction of the torpedo. The Brennan invention has been employed for harbor and coast defense of the British Empire, but the essential wires are fatal to its adoption for moving ships, which might become involved and blown up by their own projectiles. The Bliss-Leavitt and others are therefore the torpedoes for the war vessel and the submarine; and it is this deadly weapon which has brought the last-named into the fleets of the world.

A TORPEDO CAUGHT IN A NET

Seeing that many years have elapsed since Whitehead began his experiments with the modern torpedo, it may seem strange that the submarine vessel designed to give it its utmost power failed, after all the trials already narrated, to arrive before. In point of fact, it could hardly have matured a day earlier. Men had been groping for two thousand years for a successful scheme for the design of a boat which should serve them as a coast defense, and as a method of safe transport on the floor of the sea where buried treasure and secrets of science lay. The simple truth is that until quite recently the means were not available for the building of a satisfactory submarine. What are the requirements? The vessel must be able to travel on the surface of the water. It must be able safely to descend to a sufficient depth to enable it to clear the hull of a ship. It must be capable of preserving longitudinal stability under water, otherwise it would dive to destruction. It must be water-tight and air-tight, yet men within it must be able to breathe and move and live, during submersion, in comparative comfort. Finally, it must, after diving quickly, be able swiftly to ascend. It is a mistake to suppose that any epoch-marking discovery has been associated with the recent great development of the submarine. The main secret was mastered ages ago; only the materials and methods have been bettered.

The transition from manual to mechanical power of propulsion had already been effected during the Civil War, steam and compressed air both having been tried. When, in 1875, J. P. Holland began his famous sequence of boats, quite a mass of data had been gathered from the experiments of pioneer ventures; and Nordenfelt, his famous Swedish rival,

although he secured the attention of the naval world for a number of years and actually sold some of his creations to more than one country, seems, in the light of present-day knowledge, to have made his task unnecessarily difficult. French engineers followed, in 1888, with the first of



THE EYE OF THE SUBMARINE, AND A VIEW IT PROJECTS BELOW THE WAVES

The periscope is a tube fitted with mirrors which reflect a view of a section of the horizon to the officer of a submerged submarine, much on the principle of the camera obscura. The top mirror of the periscope is shown inset in a view of what, by turning, it shows.

their submarines; and Great Britain waited until 1900 before committing herself to any expression of approval. The British attitude had been all along very much that defined in the dictum of Admiral Lord St. Vincent when consulted by Pitt, who was impressed by Fulton's invention. "Pitt is the greatest fool in creation," said the bluff sailor, "to encourage a mode of war which those who command the sea do not want, and which, if successful, would deprive them of it." The race was left, therefore, between America, Sweden and France; and, brilliant as have been the triumphs of France the palm must be awarded to the United States, to whose inventor, Holland, the world is indebted for the earliest practical submarine craft.

When America began seriously to consider the question of submarines for her navy in 1885, she invited Nordenfelt and Holland to submit designs. The Norden-

felt boats, of which several were built, were driven by steam. When the boat was about to dive, the funnel had to be taken down, the fires put out, and the reserve steam used for propelling the boat beneath the surface. In order to submerge, water was drawn into the ballast-tanks, and this increase of weight was accompanied by the work of horizontal propellers, placed one on each side of the boat. The two forces combined to sink the boat in a horizontal position, for Nordenfelt could not believe that any submarine could safely attempt to descend or ascend at an angle.

The boat was a failure, owing in the main to her lack of stability. Anything which would cause her for an instant to deviate from the horizontal made the water in her boiler and ballast-tanks surge violently to and fro, and so increased the angle of inclination. She was perpetually working up and down, we are told, like a scale-beam, and no human vigilance could keep her on an even keel for half a minute at a time. On the one occasion when she fired a torpedo she nearly stood vertically on her tail; while the unexpected wash from a boat, as she was about to descend, filled her open conning-tower with water, and caused her to sink like a stone. Only the immediate blowing out of ballast-water restored her buoyancy and enabled her to rise and so save her crew.

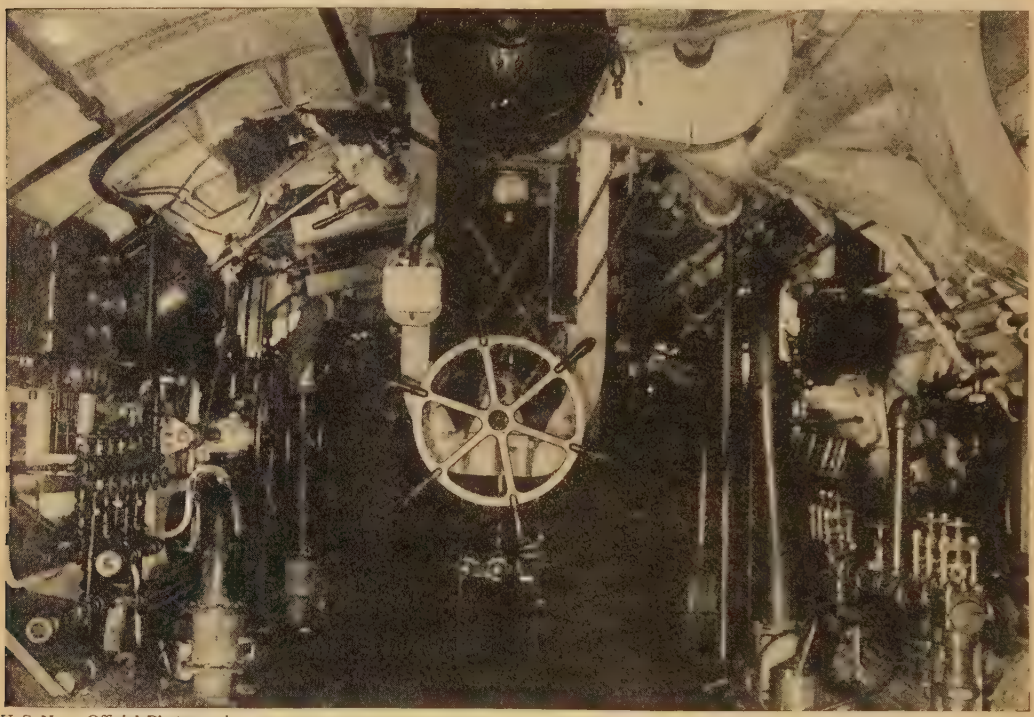
U. S. Navy Official Photographs

THE "EARS" OF THE SUBMARINE

There is a microphone in each of the three "rats" that will hear sounds 30 miles distant. They were designed during the war to detect enemy submarines.

Holland, after many trials, all on the right lines, designed a boat driven by a gasoline-engine, fitted with ballast water-tanks and diving-rudders, with electric batteries for use when submerged and abundant reserve of compressed air for breathing. This boat did not sink horizontally, as the various Nordenfelts had sunk; she descended and ascended at an angle, and maintained her fixed depth by means of her lessened buoyancy and the action of her horizontal rudders, this latter means

being effective, of course, only when the boat was moving. That, in the briefest outline, was the "Holland," with which the British government in March, 1901, announced its intention to experiment. The Mistress of the Seas had to buy her first batch of submarines of an American inventor! True, they were constructed in England, but the design was American, and permission to build the boats was given by an American firm. The policy of deliberation has been abundantly justified in the opinion of experts. From being among the latest to enter the race, Great Britain probably made herself mistress of the finest fleet of submarines in the world. She waited while other nations were experimenting, and then bought the first practicable idea, and grafted her improvements on that. She began with small craft fitted with gasoline-engines. Gasoline gives off deadly fumes in a closed chamber, and causes explosions. Due to this danger to the submarine and crew, gasoline has now been abandoned, and the heavy-oil internal-combustion engine has taken its place. Every year has brought an improvement in the internal-combustion engine. Almost as great an advance has been made in the electric storage battery. The engine propels the boat when on the surface, and also drives the dynamo which generates electricity, which is stored for use when submerged. It was the absence of these two inventions which made all earlier submersible craft impossible. Compressed air was inadequate for the swift movements required of a submarine. Steam, even if it had no other objection, required the presence of a large cargo of coal, and not only limited the vessel's sphere of activity, but, with the diminishing weight, affected the equilibrium of the boat, in spite of careful calculations as to the admission of compensating ballast-water. Until the internal-combustion engine was perfected and a reasonably effective storage battery secured, the submarine was never worth consideration except for the briefest spells of work. To-day a cruising submarine carries oil fuel enough to cruise 6000 miles or more on the



U. S. Navy Official Photograph

BELOW ON BOARD A U. S. SUBMARINE
Looking forward amidships.

surface, while its storage batteries enable it, if necessary, to travel at the rate of eleven knots an hour beneath the surface for three hours or more at a stretch without once rising to the surface. The supply of air carried in reserve is sufficient for a period of three days or more.

Another difficulty which has been overcome since the early days of submarining here is in regard to seeing and steering. At first the submarine was like a blind fish in a Kentucky cavern, but lacking that only general details can be given. Submarines are constructed in the form of gigantic fish of metal. The body of the fish is the hull of the vessel. Upon its back is a small platform, the deck, and rising above the deck is a prominence, looking at a distance like a hump. This prominence is the conning-tower of armored steel, but lighted by windows through which the navigating officer can see his course when the vessel is running only half submerged. Until terrible acci-

U. S. Navy Official Photographs

UNDERWAY ON THE SURFACE
Looking forward on deck of submarine.

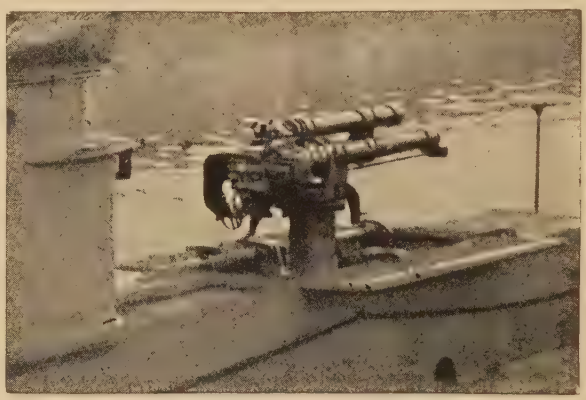
RATHER A SMALL HOLE TO GET OUT OF
Submarine hatch opened.

that creature's sensitiveness of touch. Moreover, the electric currents within made the only possible method of steering under water, by compass, hopelessly erratic. The periscope has given eyes to the submarine, and the gyroscope compass has rendered her free from difficulty as to electric currents.

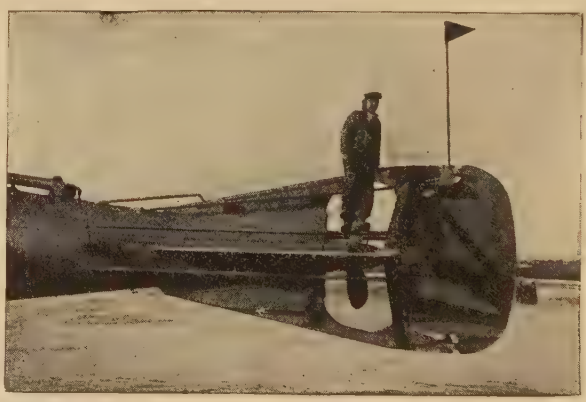
The actual mechanism of the modern submarine is one of the most closely guarded of secrets. Every man concerned in her structure is sworn to secrecy, so

dents caused by water pouring down the hatch of an unclosed conning-tower brought an amendment, this tower led directly into the body of the vessel. Now, however, the hatch at the top of the tower, through which the crew enter the vessel, has a corresponding device at the bottom, so that should a sea break over the open top it cannot penetrate into the interior. But in case of accident, as has happened, the man there on lookout duty is caught between the two hatches, a prisoner.

When the craft is about to dive, the conning-tower is closed, water is admitted into the ballast-tanks to lessen buoyancy, the engine is switched off, and electricity becomes the motive power and drives the propeller. With the electric motors running, the newest boats develop about 400 horse-power. As the propellers turn, the diving-rudders direct the vessel downwards. A depth of some 200 feet is possible, but a third or even a fifth of that is sufficient for all ordinary purposes. The buoyancy of the craft is maintained by various secret automatic appliances, and by ballast contained in what are known as the trimming and adjusting tanks. Innumerable instruments keep the crew informed as to the conditions immediately surrounding their little world. Sight does not assist, except when the periscope is consulted. The sea itself is utterly opaque for the submariner. Searchlights are useless. At present, when submerged, all that can be seen of what is taking place on the surface is through the periscope—a series of prisms by means of which a picture is reflected down a long telescope tube, to the eye of the man below. The newest submarines have two or more of these instruments, one to show objects in the immediate neighborhood, the other for objects at a distance.



A DISAPPEARING QUICK-FIRING GUN MOUNTED ON THE DECK OF A SUBMARINE



THE RUDDER, PROPELLER, AND REAR ELEVATING PLANES OF A SUBMARINE

As for hearing, when submerged, news may be received through the radio when the aërial is not more than twenty feet below the surface. As it is brought up nearer the surface messages can be heard from greater distances. A special type of radio apparatus is used for this, the details of which are kept secret by the Navy Department. In addition, messages sent in Morse code may be received from surface vessels by means of the listening devices fitted to all submarines. The distance that such messages may traverse varies from one to thirty miles, dependent upon the type of apparatus used and the smoothness of the sea.

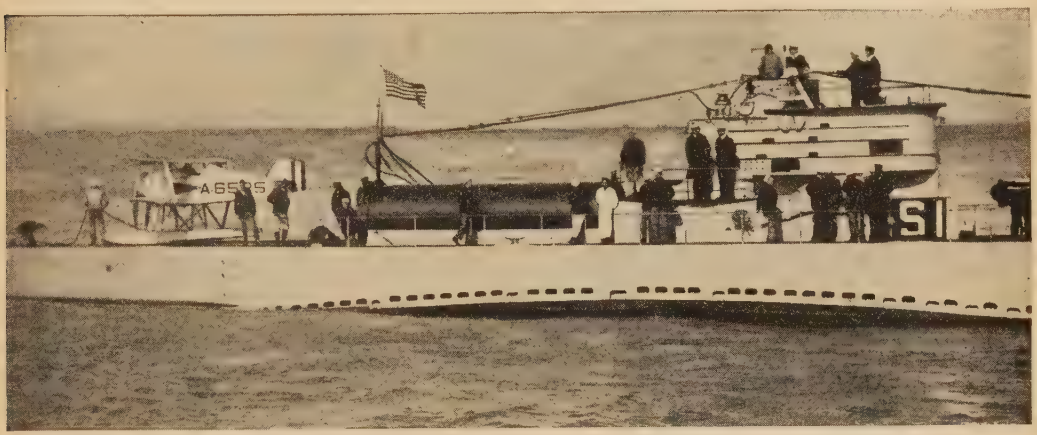
Compressed air supplies the atmosphere of the vessel when below the water, and also discharges the torpedoes which the vessel carries. Our large modern boats carry four or more torpedo-tubes, and the firing of these is accompanied by a triumph of compensatory balance. The earlier craft were so unstable that the mere movement forward or backward of one of the crew might send the vessel diving to the bottom; and we have seen what happened when the Nordenfelt discharged her only torpedo. Now, however, as the terrible projectile leaves its tube, water is admitted and passed from tank to tank with such precision and speed that balance is never for an instant affected.

The crew, between eighteen and forty-five officers and men, dependent on the type of ship, cook their food in electrically heated ovens. They partake of the same rations, share practically the same quar-

ters, carry their lives in their hands every minute of every hour, but declare themselves a happy crew. Conditions below are now so improved that it is no longer necessary to carry white mice to warn the men of the presence of carbon monoxide in the atmosphere: the carbon monoxide is no longer there.

The submarine has long passed its experimental stage. At first it was regarded simply as a means of coast defense, but it rapidly attained to the dignity of an ocean-going vessel. The Great War proved its ability to cross the ocean whether loaded with aniline dyes or torpedoes. Armed with their torpedo-tubes and their quick-firing guns — these latter mounted on a platform forward of the conning-tower — they can accompany larger ships to sea. Upon the enemy being sighted by one of the greater warships, instructions are quickly given by radio to the submarine, which, led like a dog of war to the quarry, at once dives out of sight; then, proceeding eighteen or twenty feet under water, with only the periscope momentarily peeping above the waves to guide it, it steals upon the enemy, and, the right distance having been gained and the exact position ascertained, discharges its torpedoes one after another until the enemy has been sent to its doom. Then the terror of the seas creeps away again, unobserved as it has come. The potentialities of the submarine are enormous and terrible, and the probability is that their size and power will be immensely increased.

What their future is to be in peaceful pursuits cannot be guessed; but as knowledge of contrivances which are now State secrets becomes diffused, the submarine must surely be a great adjunct to the diver. Already startling achievements have been credited to the Lake submarine, the first of which ran upon wheels along the bottom of lakes and shallow seas, exploring and retrieving cargoes sunk in moderate depths. The usefulness of these vessels in this direction must, however, be limited through the incapacity of the human constitution to withstand water pressure at more than modest depths.



U. S. Navy Official Photograph

SUBMARINE PLANE LEAVING ITS HANGAR ON THE *S-1*

The seaplane is stowed with its wings and pontoons detached. It is assembled on deck; the submarine then submerges until awash and the plane floats off.

The Great War which broke out in Europe in August 1914, was characterized on the sea by the exploits of modern submarines. The work of the German submarines was more spectacular than that of the Allies due, naturally, to the fact that the German warships and merchant vessels were kept safely bottled up in various ports by reason of the superior strength of the British Navy, while the ships of England and her allies were at sea constantly, and exposed, after the war began. Inasmuch as, at the beginning of the war, the Allies all together had about five times as many submarines as Germany and Austria, their work might have been more extensive and equally brilliant if there had been any chance for operation.

Exploits courageous and dastardly submarines in the Great War

Shortly after war was declared the British light cruiser *Pathfinder* of 3000 tons displacement, was sunk in the North Sea by the German submarine *U-21*. This is the first recorded successful attempt of a modern submarine to sink a large war vessel. Just after this, the German light cruiser *Hela* and the destroyer *S-126* were sunk by the British submarine *E-9*. On September 22, however, the world was shocked by the sinking of the three large British armored cruisers *Hogue*, *Cressy* and *Aboukir* of 12,000 tons each, by the German submarine *U-9*. Out of a total of 2200 men on these ships, only about half were saved. These were rather old ships and as such had been assigned to patrol duty. Consequently they did not have the customary protection afforded to other warships by a fleet of destroyers, and so fell an easy prey to the hostile submarine. The *U-9* was built in 1910, and was of 300 tons displacement. She carried three 18-inch torpedo tubes and two 1-pounder guns. Her surface speed was 13 knots and her submerged speed 8 knots.

After the loss of these three armored cruisers, several other warships were sunk by submarines, but most of them were small cruisers or auxiliary vessels, indicating that the British fleet found some satisfactory method of keeping its large warships safe from submarine attack. After Germany inaugurated its policy of sinking merchant ships by submarines, the most terrible instance of this was the sinking of the Cunard passenger liner *Lusitania*. This magnificent ship carrying over 1200 passengers was sunk without warning May 7, 1915, resulting in the death of 1150 persons, a large proportion women and children, and including 114 citizens of the United States. The wave of feeling aroused by this outrage hastened our inevitable entering the war. The torpedo from the submarine struck the ship midway of a boiler room, causing steam explosions to be added to that of the torpedo, and the ship sank in about fifteen minutes.

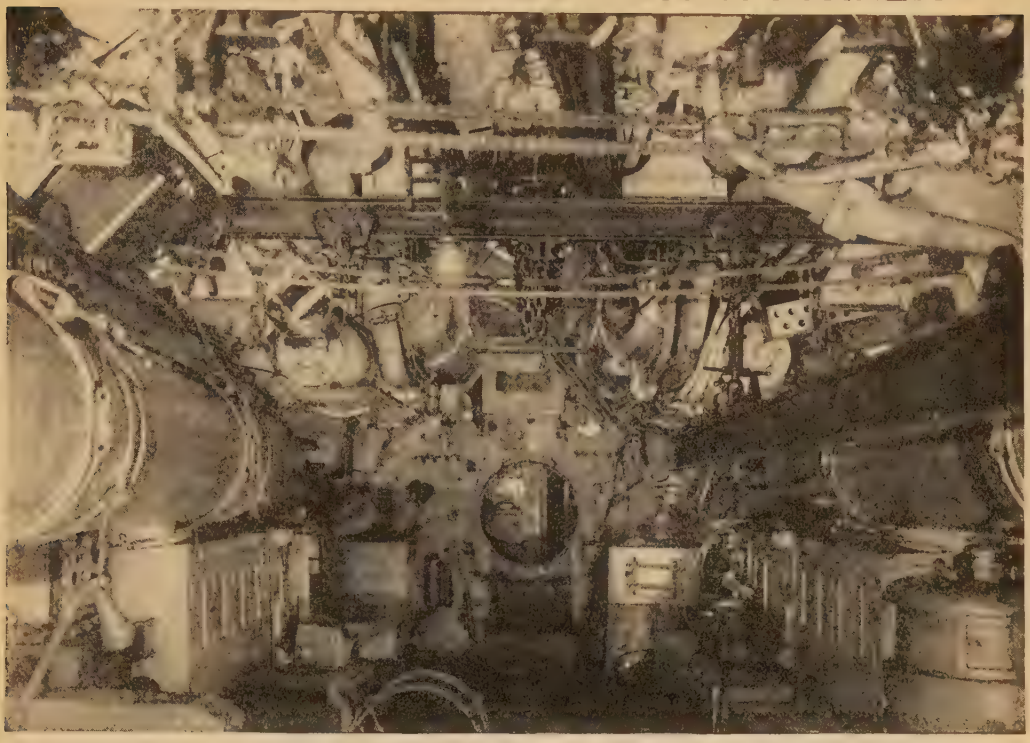
More praiseworthy exploits of submarines during the war were those of the submarines which operated in the Dardanelles. The British submarine *B-11*, after a long trip from England, succeeding in entering the Dardanelles, dived under the rows of mines anchored there, torpedoed the Turkish battleship *Messudieh* and returned safely, even after being submerged on one occasion for more than nine hours. Another instance was the torpedoing of the British battleships *Majestic* and *Triumph*, sunk by the German submarine *U-51* after she had made her way from Germany to the Dardanelles, a voyage of over 3000 miles.

The torpedoing of defenseless merchant ships, as in the innumerable cases afforded by the war, cannot be considered as a triumph for the submarine, but the sinking of an enemy's warships may more properly be taken as such, especially as the submarine is then itself subjected to great danger. If periscopes are shot away, it must sooner or later come to the surface, after which it is generally easy prey for the enemy's guns.

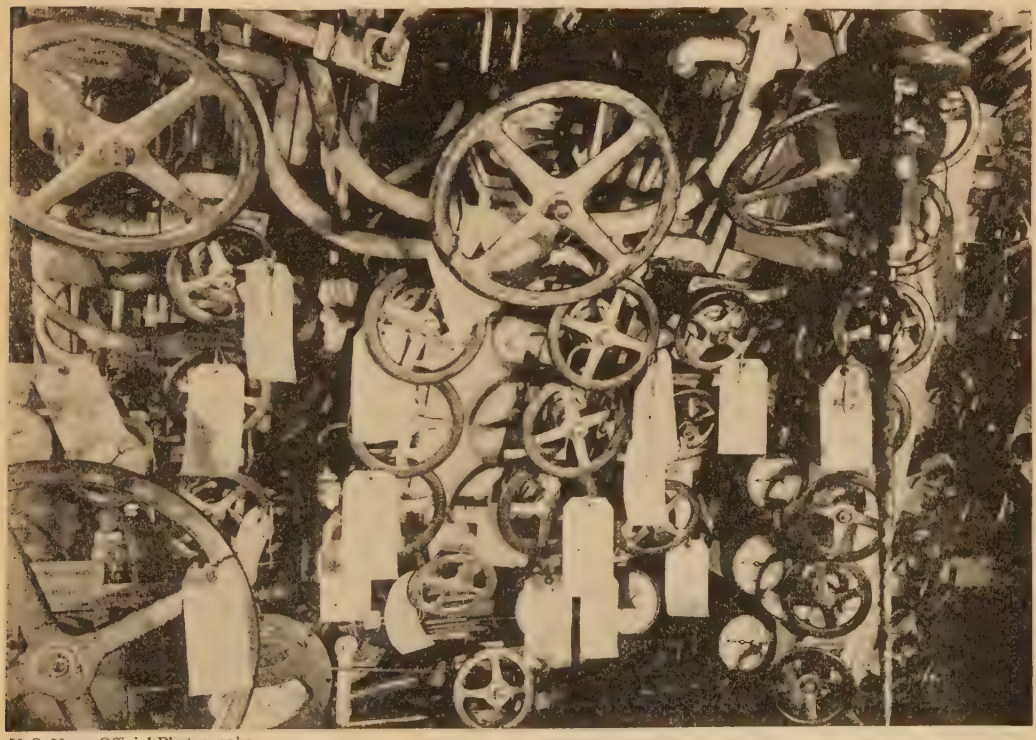
Use of submarines in opening ice-locked harbors and passing under frozen rivers

The submarine is declared to hold the key wherewith ice-locked harbors may be opened, and frozen rivers and lakes underpassed. One inventor, improving upon this, avowed his intention of proceeding by submarine under the ice to the North Pole. Happily, the advent of Commander Peary at that coveted goal prevented this mad scheme from being attempted. We had in 1913 in the United States a startling illustration of the ability of the submarine to find its way under ice. It chanced in February that Chesapeake Bay was, for the first time in many years, frozen over. The United States Navy Department seized the opportunity of seeing how submarines could cruise under ice. The course lay between a point a few miles from Yorktown, Virginia, and the Rappahannock River. At the starting point there was, of course, clear water; the goal was a space at which an ice-breaker had cut a clear passage.

EXAMPLES OF GERMAN THOROUGHNESS



INTERIOR OF GERMAN SUBMARINE



U. S. Navy Official Photographs

CONTROLLING MECHANISM ON GERMAN SUBMARINE

The tags were attached after capture to translate the German directions for the benefit of the American sailors.

Twenty submarines were dispatched upon the novel and hazardous journey. The conditions were entirely new. Once the boats dipped beneath the ice there was no possibility of rising until clear water was attained. The journey extended over thirty miles, and had to be made entirely by the aid of chart and compass. The majority of the submarines made the perilous journey with safety and exactitude, but a small minority — the precise number is known only to the Navy Department — did not keep their course, and were obliged to make for open water. The achievement of the others, however, was not unnaturally acclaimed a sensational success. The feat was one of the most surprising since a regiment of cavalry captured a ship frozen into the ice of Holland in a war of long ago.

The tragedies of submarine navigation and the lessons they have taught

Like many other of the famous inventions of man, the submarine has been productive of infinite tragedy as well as of triumph. Although the submarine rudders are remarkably sensitive and effective, and although the mechanism for discharging ballast-water, and so restoring the buoyancy necessary to bring the vessel to the surface, is quick-acting and powerful, many a brave crew has found the submarine but a steel tomb of marvelous but unavailing complexity. Submarine has collided with submarine, with warship and with steamer. The failure of a valve-spring, causing an escape of gasoline, flooded one submarine with gas and rendered its crew helpless.

The starting of a single rivet is held responsible for the loss of another, though quite inadequate reserve buoyancy was, too late, detected. The use of a broomstick thrust out of the open conning-tower, as a signal to a sister vessel, led to the shipping of a sea and another disaster. The perils of the submarine are diverse and many.

The only consolation is that each accident has taught its lesson. The broomstick signal has yielded place to radio. The gasoline-engine has given way before the heavy-oil engine, from which neither poisonous nor combustible fumes escape. But there remains the fatal blind spot — that period of sightlessness in which the submarine is climbing up from below to thrust her periscope into the air. The submarine is still "blind" when her periscope is submerged; and as she rises she may at any moment strike another vessel which is moving at speed in the same area. The disaster to the French submarine *Vendémiare*, involving the loss of her two officers and twenty-three men, which happened several years ago is, unfortunately, only one of several cases in point.

The necessity of remedying the submarine's blindness when periscope is submerged

The submarine must be rendered able to "see" or to "feel" while actually submerged. Possibly the necessary invention will take the form of an electrical device sufficiently sensitive to record the presence and position of a metallic body in the neighborhood of the submarine. Some such protection is absolutely necessary to the safety of every submersible craft; and it is not unreasonable to hope that the United States, as the possessor of great inventive talent, may be the source from which this essential life-saving apparatus shall spring.

Whether the perfecting of the submarine will be one of the means whereby the building of sea monsters at an enormous cost will be made futile owing to the mastery over them of this destruction which both "walketh in darkness and wasteth at noonday" is one of the exciting problems of a future that seems near at hand. The bullet killed the armored knight as an institution without needing to kill many of him in actual warfare; and it is possible that one or two dreadful successes by these deadly prowlers under the waters, combined with the perhaps equally deadly scout from cloudland, bomb in hand, may make the floating fortresses of the early twentieth century into relics preserving the memory of one of man's costly mistakes. In the meantime efficiency in submarines and in dreadnoughts goes hand in hand.

LOOKING UP AND LOOKING DOWN

SQUADRON OF AIRPLANES SEEN FROM THE DECK

U. S. Navy Official Photographs

SUBMERGING SUBMARINE SEEN FROM THE AIRPLANES

Commercial submarines and the distinct achievements of the *Deutschland*

In the Great War, the military achievements of submarines in sinking warships and merchant vessels must be given their proper share of attention but those of the submarine merchant ship *Deutschland* command still more respect. This submarine was built, not for the purpose of destroying the enemy's warships, passenger or cargo boats, and the people on board of them, but in order to carry cargo between the United States and Germany in spite of the blockade of German ports by the British Navy.

Due to the ability of a submarine to submerge itself when a hostile vessel is in sight, the *Deutschland* was able to thread her way through the fleet of British patrol boats, mines, nets, etc., in the North Sea and English Channel, and make two successful voyages to this country and return. The undertaking was especially dangerous on account of the large number of nets which the British Navy had spread in the waters of the Channel for the purpose of capturing submarines. Once a submarine has her rudders or propellers caught in such a net, she is helpless, and then must either come to the surface to be captured by the patrol boats, or else she cannot rise, and the crew meets death by drowning or suffocation.

The *Deutschland* was not a converted submarine of the German Navy, but was built for the special purpose of carrying valuable cargo. Consequently she had no guns or torpedo-tubes. Her length was about 300 feet, breadth 30 feet, and depth of hull, 17 feet. In order to completely submerge she required water somewhat over 30 feet deep. Her general appearance was not unlike that of the whaleback steamers seen on the Great Lakes in this country. A narrow deck about six feet wide, tapering at the ends, extended from bow to stern at a height of about two feet above the curved hull. The navigating bridge was located near the middle of the boat, and was about 25 feet above the water when the vessel was running on the surface. Telescopic masts for the wireless and the usual periscopes were also provided. The hull proper consisted of two shells, an outer and an inner. The former was oval in cross-section, and gave the boat its ship-shaped form, thus affording better lines, speed and sea-going qualities than could be obtained with an ordinary circular, spindle-shaped hull. The inner hull, however, was circular, and was so designed as to withstand the great pressure of the water when the boat was submerged.

The interior arrangement was quite different from that in a naval submarine. Since neither torpedo-tubes nor torpedoes, nor guns nor ammunition were carried, the space usually occupied by these could be used for cargo. It is stated that nearly one-third of the interior space of the boat could thus be used, or in other words, about 600 tons of valuable freight could be stowed on board of the *Deutschland*. No provision was made for carrying passengers.

The machinery for driving the boat on the surface consisted of two six-cylinder, heavy-oil engines of the Diesel type, of about 600 horse power each. These engines were capable of giving the boat a reported maximum speed of about eighteen knots, but for ordinary traveling, her speed was about fourteen knots. When running submerged, the boat was driven by electric motors run by storage batteries. These gave her a maximum speed under water of twelve knots, although ordinary conditions do not require such fast running. Her first trip from Bremen to Baltimore was made in about sixteen days. Her crew was composed of three officers and twenty-three men.

Submarines of the *Deutschland* type are not only very valuable in a commercial sense as blockade-runners, but they might also be used by a navy as auxiliary ships in which ammunition, fuel, stores, etc., could be carried without the enemy's knowledge to a fleet far from home.

PIONEERS V

BERNARD PALISSY — THE HEROIC PRINCE OF FRENCH POTTERS
JOHANN HEINRICH PESTALOZZI — A KINDLER OF ENTHUSIASM FOR EDUCATION
SIR ISAAC PITMAN — THE POPULARIZER OF SHORTHAND
HENRI POINCARÉ — MATHEMATICIAN AND PHILOSOPHER
JEAN JACQUES ROUSSEAU — WHO WROUGHT REVOLUTIONS WITH A PEN
JACOB GOULD SCHURMAN — TYPICAL OF THE BEST IN UNIVERSITY EDUCATION
JOSIAH WEDGWOOD — THE KING OF ENGLISH POTTERS
WILLIAM WILBERFORCE — THE GREAT EMANCIPATOR
FRIEDRICH WÖHLER — PIONEER IN ORGANIC CHEMISTRY
WILBUR AND ORVILLE WRIGHT — THE FIRST MEN TO FLY

BERNARD PALISSY
The Heroic Prince of French Potters

BERNARD PALISSY, the prince of French potters, was born at either Saintes or Agen, in or about the year 1510, and was apprenticed to a glass-painter. Afterwards he became, as was the custom for men of his type, a wandering craftsman. His travels led him through the Netherlands and part of Germany, as well as over the greater part of France, and during this time he acquired a knowledge of land-surveying, which was to prove serviceable to him in later years. A faithful student of nature, he observed bird and beast and flower, with results which will presently be shown. He settled down at Saintes, and there married, when some twenty-eight years of age. He earned a livelihood by painting on glass, by land-surveying, and portrait-painting. Then there came into his life an all-absorbing passion, kindled by the sight of an enameled cup of exquisite workmanship, embellished by the loveliest of translucent enamels. Now, to what school of art pottery this special piece belonged, whether to that of Luca della Robbia or to the Chinese school, cannot be determined, but expert opinion inclines to the Chinese.

Palissy, who knew nothing of the craft save such rough-and-ready experience as he had gained of peasant pottery, determined to make an enamel of his own. He tried innumerable experiments, as he was bound to do, for he had no books upon the subject; nothing was known, and he was unable to leave his family and travel in quest of such knowledge as might be expected to exist. He could only conduct his own unassisted experiments, trying combination after combination of materials and chemicals, breaking up pottery and mixing the fragments with his compounds, and burning them in the furnace he had made. Failure succeeded to failure, yet each fired him with firmer determination to succeed. Pots and fuel, fuel and pots — these were his constant demand, and his purchases and the time given to the work brought him to abject poverty. With a little family growing up about her, his wife not unnaturally resented what seemed to her a visionary quest, the certain issue of which appeared starvation for herself and her children. But Palissy kept on, and at the end of two years of frenzied labor produced, from a kiln of 300 pots, one which bore a white glaze, which he described as singularly beautiful.

He had, in the meantime, been compelled to carry his wares to a tile-furnace four miles away. Now that he seemed on the track, he set out to build himself a new furnace at his own home of the type in which he had gained his one success. He built his furnace single-handed, carrying the bricks upon his back from the brickfield, and laying them without assistance. He

procured a large supply of fuel, started his fire, and waited for his enamel to melt and diffuse itself over his pots. It refused to yield. All through the night he stoked his furnace, and all next day, never leaving his fire for more than a moment or two; all the next night, and so on for six days and nights — all for nothing. Then he tried a new flux, and he staked his all upon the trial. He reached the end of his fuel, and burned the garden fence. Still the enamel had not yielded; he burned the household furniture, and after that the

BERNARD PALISSY

very pantry shelves. And while his wife and family ran wailing through the town, crying that Palissy had gone mad, and was breaking up the home for firewood, the enamel melted, and the brown household pots, that went in unlovely, came out of the furnace coated with a beautiful enamel.

Feeling that success was assured, he engaged a potter to work for him, but was so poor that he could only give the man his clothes in lieu of payment, while he begged food and lodging for himself of a friendly innkeeper. When at last the first trial came, flints which he had employed when building his furnace cracked and burst, and, though the enamel proved right, it was covered with debris from the flints. Six months' hard work had gone to this failure, but Palissy would not sell his wares; he smashed them because they were imperfect; and amid the mockeries of his fellow-townsmen and the reproaches of his family he continued at his work.

His courage and hope were incomparable. "Sometimes," his autobiography tells us, "when visitors called, I entertained them with pleasantry, while I was really sad at heart. . . . Worst of all the sufferings I had to endure were the mockeries and persecutions of my own household, who were so unreasonable as to expect me to execute work without the means of doing so. For years my furnaces were without any covering or protection, and while attending them I have been for nights at the mercy of the wind and rain. . . . Sometimes the tempest would beat so furiously against the furnaces that I was compelled to leave them, and seek shelter within doors. Drenched by rain, and in no better plight than if I had been dragged through mire, I have gone to lie down at midnight or at daybreak, stumbling into the house without a light, and reeling from one side to another as if I had been drunken, but really weary with watching, and filled with sorrow at the loss of my labor after such long toiling. But, alas! my home proved no refuge; for, drenched and besmeared as I was, I found in my chamber a second persecution worse than the first, which makes me even now marvel that I was not utterly consumed by my many sorrows."

For sixteen years these unparalleled efforts continued, and at last success was achieved. Although a staunch Huguenot, Palissy was protected by the Constable of Montmorency, who desired that the enameled tiling of his new palace should be completed. By the constable's influence Palissy was appointed inventor of rustic pottery to the king and constable, and he moved to Paris, where he established himself on the site of what afterwards became the Tuileries, so-called from its being the place of the tile-burners.

Palissy's troubles now seemed at an end. Assisted by his sons, he carried on his pottery work under the best auspices, and had leisure for other pursuits. He wrote on pottery, on natural history, on the cause of earthquakes, on fortification, on water-supply. His close observation of nature enabled him faithfully and beautifully to reproduce not only existing forms but extinct forms of life. "It was reserved for a potter without either Latin or Greek," wrote Fontenelle, "to have the hardihood, in the latter part of the sixteenth century, to declare in Paris, and in the face of all the doctors, that the fossil shells were real shells, deposited by the sea, once upon a time, in the places where they were found, and that animals had given to the figured stones all their different figures, and boldly to defy the school of Aristotle to attack his proofs."

We all know today that Paris and the Sphinx and the Great Pyramid are built of exactly the same material. Paris is founded on extinct nummulites, and the two landmarks of Egypt are composed of rock consisting entirely of fossil shells of the same form of life. But to declare such a thing in Palissy's day was considered rank heresy. In 1588 he was cast into the Bastille, and condemned to death, but he died before the sentence could be carried out.

Palissy's best-known productions are the *pièces rustiques*, plates and platters ornamented in bold relief with fish, shells, snakes, plants and lizards, true to nature in color and form. In the Metropolitan Museum (J. P. Morgan collection) are some of the more unusual mythological subjects. The Louvre and Cluny Museum are rich in Palissy's handiwork, and at Sèvres there are also some fine pieces. His plates and ewers molded in facsimile of delicate works in pewter of François Briot and other Swiss metal-workers are among his most successful and artistic work. Palissy wrote on a great variety of subjects, such as agriculture, natural philosophy and religion. In his *L'Art de Terre* he gives an account of his processes and how he discovered them. His literary works, including a stirring autobiography (edited by Anatole France), justify the high place Lamartine gives him among French writers.

ONE OF PALISSY'S MASTERPIECES

Platter ornamented with fish, snakes and shells in bold relief and in their natural colors.

JOHANN HEINRICH PESTALOZZI
A Kindler of Enthusiasm for Education

JOHANN HEINRICH PESTALOZZI, one of the most distinguished of educational reformers, was born at Zurich, Switzerland, on January 12, 1746. His father, a physician, died when the boy was five years old. Brought up by an unselfish mother, he grew good-natured, dreamy, and sympathetic, but reserved, and incapable of guarding his own interests. At school his guilelessness exposed him to the banter of his companions. He was not precocious, nor was he dull; but he was never at any time proficient in reading, writing or arithmetic. From the elementary school he proceeded to the University of Zurich, where he made some progress in theology. As a student he was one of a little band of reformers smitten with a passion for the ideas of Rousseau, and it was in a college magazine that Pestalozzi first disclosed his views on education. "I would," he says, "that someone would draw up in a simple manner a few principles of education intelligible to everybody." And he would have such a pamphlet distributed "to fathers and mothers, so that they might bring up their children in a rational and Christian manner".

Pestalozzi was already deeply interested in the problems created by the inequalities of society; the privileges of the rich jarred harshly on his sensitive spirit as he contemplated the distress, ignorance and universal want of his countrymen. Of himself and a knot of fellow-students he says, "We decided to live for nothing but independence, well-doing, and sacrifice for love of country"; and he avows his chief purpose in life was to secure a happier fate for the poor of his native land, by improving and simplifying their educational privileges. His intention of becoming a clergyman was disturbed by the failure of his first sermon; so, with the same resolution to turn his education to the advantage of others worse situated than himself, he began the study of law. However, it ended in the burning of his legal manuscripts, and his decision to become a farmer.

With philanthropy as his guiding motive, Pestalozzi then borrowed money, bought a farm of a hundred acres, and made his object the cultivation of madder, and the instruction of the peasantry in better and more profitable methods. In the midst of this new venture he married (1769) Anna Schulthess, a young lady of considerable means, and seven years his senior. One of his love-letters is a model of candor and self-revelation. He confesses his utter indifference to polite conventionalisms; his improvidence, his inability to grapple with emergencies and his patriotism, which, if called upon, would urge him to risk all to alleviate the misery of his fellow-creatures. But Fräulein Schulthess was undaunted, and shared his struggles for over fifty years. In five years his farming enterprise had to be abandoned. He was "an agricultural visionary", and admits that his failure arose from his pronounced incapacity for every kind of undertaking which requires practical ability. Here, again, considerations of self were submerged in his zeal for humanity. In this spirit of self-abnegation lay his lasting influence as a teacher.

For Pestalozzi was determined to make a great educational experiment. He converted his large farmhouse at Neuhof into a school (1774). He began with twenty poor children. He fed, clothed and lodged them in return for such work in the fields or at the distaff as he might require of them. The children often learned their lessons while they worked with their hands, for Pestalozzi used conversation on common objects as a primary means of conveying information. In a few months, love, gentleness and care had transformed these poor little creatures into hearty, intelligent beings. It was the first "industrial school."

News of his success quickly spread. Pestalozzi claimed to have proved that health lost through idleness or mendicity can be repaired by systematic work; that the most depraved are touched by kindness; and that the abjectly poor brought up in private establishments where manual and mental instruction are suitably blended can be raised to a higher and happier plane of life. Sanguine as ever, he enlarged

his undertaking, but his almost total incapacity for administration plunged him into bankruptcy. In 1780 his wife's fortune had disappeared, and for eighteen years he was destitute.

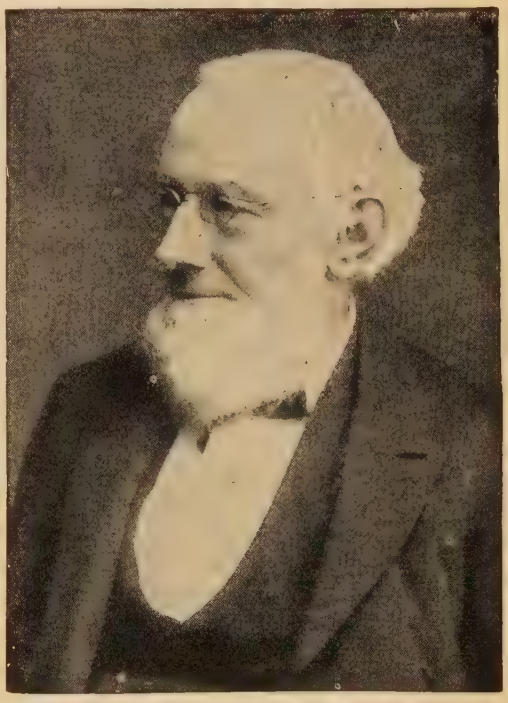
He took to authorship, and his popular book "Leonard and Gertrude" was published in 1781. It is also his best book; and from its pages and those of "How Gertrude Teaches Her Children" (1801) may be gleaned the leading principles upon which Pestalozzi founded his system. He believed in the magic of the teacher's personality. His most important aim was the concurrent and harmonious development of all the faculties that a child possesses. The child must be encouraged to acquire knowledge through the energetic exercise of its senses.

Instruction should be founded on observation, especially with infants. Object-lessons are of the utmost value. A child must be put into actual contact with concrete things, and infer their nature from handling and examining them. There are three classes of object-lessons, applicable to form, number and speech. They are intended (*a*) "to enlarge gradually the sphere of the child's intuition; (*b*) to impress upon him those perceptions of which he had become conscious with certainty, clearness and precision; (*c*) imparting to him a comprehensive knowledge of language for the expression of whatever had become or was becoming an object of his consciousness." The higher needs of the intellect were not to be overlooked; mathematics, history and music should receive due attention. But the most potential principle that Pestalozzi brought into the schoolroom was love; and his message to the world was that education was the richest of all gifts, whether it be to rich or poor.

When fifty-three years old, Pestalozzi left Neuhof, and resumed school work at Stanz. From thence he went to Burgdorf, and finally to Yverdon, on Lake Neuchâtel (1804). Yverdon has been named the Mecca of Pestalozzianism. There the educational career of the celebrated teacher came to a close in 1825. He died two years afterwards, at Brugg (Aargau), on February 17, 1827, at the age of eighty-one.

SIR ISAAC PITMAN
The Popularizer of Stenography

SIR ISAAC PITMAN, the man who brought to predominance a single system of shorthand throughout the world, until it was written with a considerable degree of expertness by probably half a million people, was born at Trowbridge, England, on January 4, 1813. His father was engaged in the woolen trade, first as an overseer in a factory and afterwards as a manufacturer. The son began life as a clerk,



SIR ISAAC PITMAN

but became a teacher and continued in school work until 1843, though increasingly his time was taken up in popularizing his phonographic system of shorthand, which had been introduced to the public in 1837 in a book entitled "Stenographic Soundhand." A second edition came out in 1840. Two years later Pitman started *The Phonetic Journal*, which he edited for more than fifty years. The jubilee of the system was commemorated in 1887, and in 1894 its founder was knighted.

The number of books for the teaching of phonography issued by the Pitman firm

before the death of its head on January 22, 1897, was counted in millions. Although, of course, there are many systems of shorthand, Pitman's system practically commands the field in England and is the one in general use.

Complaints are sometimes heard that the system is difficult, and, unless freely sprinkled with vowel-sounds, is not legible, but there is no easy way to shorthand. Under no circumstances can the hand move as quickly as the tongue can speak without long and careful training, and pretenses to produce a cheap and easy system have always been delusive. The Pitman system, when properly known, and when practised till the writing becomes spontaneous and almost instinctive, is not only effective, but it is beautiful in its flowing outlines.

It was Pitman who suggested the use of stamps as a means of collecting prepaid postage when the English government offered a prize for the best method.

HENRI POINCARÉ
Mathematician and Philosopher

WHEN Jules Henri Poincaré, already a member of thirty-five learned societies, was, in 1908, made a member of the French Academy, Fredéric Masson recounted his scientific career in minute analysis. We are satisfied that the master early showed his tendency to the study of astronomy, as turning to him M. Masson said: "You did not delay revealing your vocation and will be justly cited as the most precocious of infant prodigies. You were nine months old when for the first time as night came your eyes were directed towards the sky. You saw there a star light up. You persistently pointed it out to your mother, who was also your nurse. Then you discovered another with some astonishment, and your reason cried 'Erico lo la bas!' A third, a fourth, more cries of joy and equal enthusiasm. You had to be put to bed because you became so excited discovering stars. That evening was your first contact with the infinite, and you had inaugurated your courses in astronomy, the youngest professor known."

Continuing in a spirit of eulogy, rather than of raillery, M. Masson said: "M. Poincaré has a vast mind. He is remarkable by the diversity and the depth of his knowledge. He is not only a geometer, but also a physicist and an astronomer, not in the fashion of those scientists who give themselves up to observations and experiments, but by the applications he has made of analytic method to science; in other words, he has advanced mathematical physics and celestial mechanics.

"As a geometer, his writings on the theory of numbers, on integral calculus, and on the general theory of functions are spread through more than one hundred and fifty Notes published in the *Comptes rendus* of the Academy of Sciences, and at least as many articles and memoirs in French and foreign mathematical journals.

"Professor of mathematics at the University of Paris he has published fourteen volumes of lessons on light, electricity, thermodynamics, and the propagation of heat, making known in France the theories of Maxwell as substantiated by Herz. He has not even neglected wireless telegraphy — an application of the Herzian waves.

"Also on the astronomical side he has shown much originality; there, his studies on the form that a fluid mass takes, when in rotation and submitted to universal gravitation, have led to universal theories concerning the breaking apart of the earth and the moon, and on the formation of diverse variable stars; his work on the stability of the solar system has led, by a revision of the calculus of Laplace and by an approximation pushed still farther, to the proof that the theory as formulated in 1784 is absolutely justified. The three volumes that he has published on celestial mechanics are authoritative amongst astronomers." In addition to this work on pure and applied mathematics, Poincaré has written three remarkable books in which the philosophic significance of science is studied with rare depth. "Beginning with a study of the forms of scientific reasoning in 'Science and Hypothesis,' he passes, in the 'Value of Science' to the problem of their contact with fact, and arrives at an interesting Pythagorean definition of the objective as nothing but mathematical relations. In 'Science and

Method' there is presented an admirable study of creative imagination showing its peculiarly intimate connection with esthetic processes. This is followed by a review of the methods of mathematics, mechanics and astronomy which includes a highly illuminating estimate of the significance of that disruption of our most cherished physical concepts which has been instigated in contemporary science by such discoveries as that of radio activity."

Such is the verdict of distinguished scientists upon the varied attainments of Henri Poincaré. For him, science was so much a living thing that growth of a part was not to be distinguished from growth of the whole. No one understood better than he how the solution of a single problem spread its influence, like the splash of a stone in a pool, until it permeates the whole. No one demonstrates more emphatically than he that the end of science is *not* purely utilitarian. "Was I wrong in saying that it is astronomy which has made us a soul capable of comprehending nature; that under heavens always overcast and starless, the earth itself would have been for us eternally unintelligible, that we should there have seen only caprice and disorder; and that, not knowing the world, we should never have been able to subdue it? What science could have been more useful?" ("Value of Science," p. 88.)

The circumstances of M. Poincaré's life can be briefly told: for it is in the world of thought rather than in the world of action that he has "inscribed tablets". Born at Nancy on April 29, 1854, the son of an eminent physician and the cousin of Raymond Poincaré, the statesman, and Lucien, the physicist, he was educated at the *Lycée* of Nancy, the *École Polytechnique* and the *École Nationale Supérieure des Mines*, and received his doctor's degree from the University of Paris in 1879. Two years later he was given the chair of Mechanics, at Paris, by the Faculty of Sciences, and he also occupied successively the chairs of Mathematical Physics, of Mathematical Astronomy and of Celestial Mechanics. At thirty-two he was elected to the Academy of Sciences.

He was made a foreign associate of our National Academy of Sciences, and was similarly honored by almost every other scientific society of the world. He received the prize offered by King Oscar II, of Sweden, for work on the problem of three bodies, the gold medal of the Royal Astronomical Society of London, the Sylvester medal of the Royal Society of London, the Bolyai prize of the Hungarian Academy of Sciences, the Lobatchefsky gold medal of the Kasan Mathematical Physics Society, two prizes from the Paris Academy, and a gold medal from the French Association for the Advancement of Science. Honorary degrees were bestowed upon him by the universities of Cambridge, Oxford, Glasgow, Brussels, Christiania and Stockholm. For fifteen years he was, by common consent, given first place in every gathering of scientific men which he attended. He died on the 17th of July, 1912, at the zenith of his intellectual powers. The world can fittingly apply to Poincaré's share in the search for truth, his own words from "*Savants et Écrivains*", "Just as humanity is immortal, although men suffer death, so truth is eternal, although ideas perish, because ideas beget ideas as men beget men."

JEAN JACQUES ROUSSEAU

Who Wrought Revolutions with a Pen

JEAN JACQUES ROUSSEAU, one of the most potent of the world's revolutionists through the use of a pen, and quite the strangest medley of a man who ever played the rôle of a prophet in the realms of sentiment, government and education, was born in Geneva, on June 28, 1712, of a French refugee Protestant family. Rousseau is one of the few men who has told the world his own story with a frankness that in anyone else would seem like malice. His mother died when he was born; his father was a restless, dissolute dancing-master, who, after feeding his weakly son's mind with wild romances, deserted him. For thirty-seven years Rousseau lived a life of failure, without securing a rag of character as a recommendation. In youth he failed first as apprentice to a notary, then as apprentice to an engraver. For twenty

years, having run away at the age of sixteen, he was a vagrant — sometimes a servant, sometimes a secretary, sometimes a teacher of music, of which he knew little, or a copier of music; now a Catholic pervert, now a Protestant deist, but always immoral, following his own whims, and never taking on himself the duties of manhood. The five children of the rough servant girl who followed him through the greater part of his life, and with whom he eventually went through a marriage ceremony, were all left to public charity as foundlings, and lost sight of. At no time in his life did Rousseau do more than earn a bare living, and usually he was dependent on people whom he affected to despise, and towards whom he felt no gratitude. Yet this weak, coarse, dissolute man, whose life was a monotonous record of dissatisfaction and petty feeling, who was uneducated, untrained in thinking, who wore out the patience of every friend, and at last, probably, ended by suicide a career of self-torture, was the literary mainspring of the French Revolution, strikes the keynote of the Constitution of the United States, holds a place in every work on the education of children, thrusts a word of argument into every discussion on the bases of public government, and has engraved on his tomb the words: "Here lies the man of nature and of truth".

Before suggesting how this came about, we must trace his life rather more in detail. The more reputable part begins in 1749, when he gained the prize offered by the Academy of Dijon for the best essay answering the question: Has the restoration of the sciences contributed to purify or corrupt manners? Three years afterwards the same academy offered another prize for the best answer to the question: What is the origin of inequality among men, and is it authorized by natural law? This time he did not gain the prize, but he arrested public attention and won such a place among the writers of the day as brought society buzzing around him, eager to know and patronize him. The argument with which he startled the worn-out artificial world of monarchical France was that culture and citizenship are huge mistakes, property is a wrong, and government a tyranny, and happiness and virtue are found in pristine purity in savage life, or in a life of supreme simplicity nearest to nature.

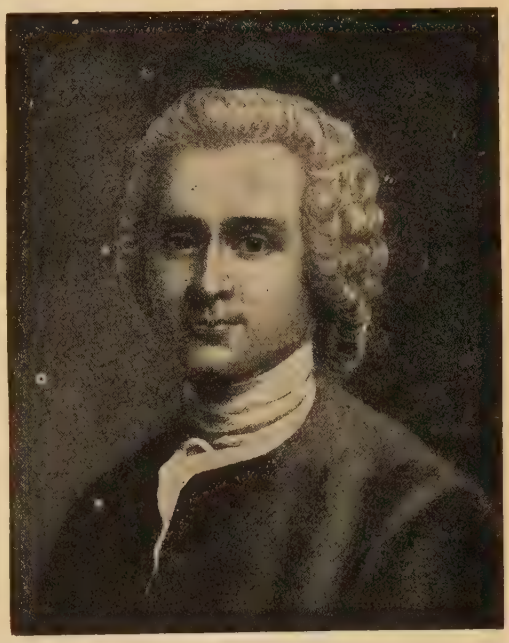
He was now offered a cottage in a forest by an admirer, and, practising his simplicity, lived there, or in another cottage close by, while he gave the world in three years three books on which his fame rests. These were a sentimental romance, "The New Héloïse", in letters after the manner of Richardson; the "Social Contract", an examination of the foundations of government; and "Émile", a biographical treatise on education, with views, by the way, on governments and religion. These works, two of which were published in Amsterdam to escape the censor, offended all the authorities, but eventually captured the imagination of the French people. The immediate result was that the books were publicly burned and the arrest of the author was ordered, but Rousseau escaped to Switzerland. There, however, the Genevan government arranged for his arrest should he enter his native city; and the Canton of Berne gave him fifteen days to leave its territory. Accordingly he passed into the principality of Neuchâtel, which then belonged to the king of Prussia, whose deputy was a sturdy refugee Scotchman named George Keith. Frederick the Great not only gave him shelter, but requested the governor to give him any necessaries he would accept. These Rousseau declined, with perhaps unnecessary preachings. "You wish to give me bread," he wrote. "Is there none of your own subjects in want of it? Take that sword away from my sight; it dazzles and pains me."

Though Frederick would have Rousseau in his territories, Frederick's subjects would not, and, after three years' petty persecutions by the villagers, forced him to leave the Neuchâtel district and take refuge on an island in Lake Bienne in September, 1765. But the island was under the jurisdiction of Berne, and the government once more moved him on. In December he arrived in Paris; and in January, 1766, David Hume, who was then secretary to the English

embassy, moved by the representations of his countryman George Keith, brought the homeless wanderer to England, and settled him at Wootton, near Ashbourne, in Derbyshire, in a house permanently lent him as a visitor of distinction.

While he was in England, Rousseau wrote his "Confessions" and his "Botanical Dictionary", and here he took a mental turn but little divided from madness. After staying eighteen months in Derbyshire, he slipped out of the country, obsessed by the idea that Hume, who had shown him every kindness, was his enemy. Indeed, during his remaining years, spent in different parts of France, where he was unmolested, he suffered from imaginary enemies and spies, and his only sane writings were those which tell of his "Musings in Solitude", and were "the melodious expression in the music of prose of a darkened spirit which yet had imaginative visions of beatitude". Rousseau died suddenly on July 2, 1778, under circumstances that suggest suicide, though the doctor's certificate named apoplexy as the cause. During the last few years of his life he was poorer than usual; and he had always been poor.

The influence of Rousseau's writing depended largely on the surroundings in the midst of which he wrote. The feeling was abroad that there was something very wrong with the world, and in whatever he wrote he began by clearing the ground of all existing institutions, traditions and methods. In his prize-seeking "Discourses" he simply swept away civilization and all the sciences and made a new start, as if with the primitive man whom he imagined as the best of men. Was it governments that he was considering — then he ruled out kings, aristocracies and all existing powers, and based the state upon a social contract between each individual and the whole community. Each individual surrenders his will to the will of all in order that he may receive protection, and the whole community is pledged in return to defend him from injustice. The whole community is thus sovereign by the will of each member of the community, and kings or other governors have no powers but by popular assent. The sovereign people living in equal citizenship became the watchword of the revolution that followed when Rousseau's influence had done its work. Was it education that he was dealing with — then he swept away the existing methods. The child is born good, was his cry; beware how you contaminate it by a false education. Till the age of twelve he would not let the child know what a book is. He would exercise the body, the senses, the perceptive powers, but in the simplest way while childhood is ripening naturally, sheltering it meantime from harmful experiences. The aim of early education must be to prepare



JEAN JACQUES ROUSSEAU

for the complete living that comes later. The education must be an education by things through the senses, and not an education of words which to the child means little or nothing. The child should have the chance of acting for itself, thinking for itself, and not be directed, but only unobtrusively guided. In all this was much good sense — with some exaggeration — but far wiser than the rule-of-thumb methods that Rousseau sought to sweep away. He based education on a study of the child.

But in all his writing Rousseau, the contemner of words, was chiefly a word-spinner. His knowledge of life was limited.

His theories were all sudden thoughts which he built up by wordy defenses. The state he imagines is not a real state; the child he teaches is not a real child living its necessary life, any more than his "noble savage" was a real savage. The systems he builds up are, as Morley conclusively argues, but expansions of his own phrases, "logical deductions from his own verbal definitions, wholly meaningless in connection with real human nature and the visible working of human affairs".

But Rousseau caused people to pause by his bold contradictions and paradoxes; he did so by virtue alike of the freshness of his thought and the charm of its expression. Untrained as a writer till he reached middle age, he had "the gift of the golden mouth", and he was the first genuine man of the people to interpret the dumb masses. "It was in Rousseau that polite Europe first hearkened to strange voices and faint reverberations from out of the vague and cavernous shadow in which the common people move."

JACOB GOULD SCHURMAN
Typical of the Best in University Education

JACOB GOULD SCHURMAN was born at Freetown, Prince Edward Island, May 22, 1854, the descendant of a New York Dutch family. He lived on his father's farm until he was twelve years old, but in 1869, after two years as clerk in a general store in Summerside, decided that he needed a wider education. Accordingly for one year he attended the grammar school of Summerside, and then on a scholarship entered Prince of Wales College, Charlottetown. In 1873–1875 he was a student in Acadia College. In 1875 he won the Canadian Gilchrist scholarship at the University of London, where he was graduated (A.B., 1877, A.M., 1878). For a year he was a student in Paris and Edinburgh, becoming D.Sc. of the latter university in 1878. Then he won a Hibbert traveling fellowship open to graduates of all British universities, worth $1000 a year and studied for two years in Heidelberg, Göttingen, Berlin, and in Italy. Returning to Canada he was for a short time professor of philosophy, political economy and English literature. In 1886 he went to Cornell as head of the department of philosophy, and in 1892 succeeded Charles Kendall Adams as president of the university. This office he retained until June, 1920, though absent on public service in 1899 as president of the first Philippine Commission, and in 1912–1913 as minister to Greece and Montenegro. In 1915 he was elected first vice-president of the New York State Constitutional Convention. In 1921 he was appointed minister to China.

In his address entitled "A Generation of Cornell" given June 16th, 1898, at the thirtieth annual commencement of Cornell University, the president sums up the position and ideals which the university had stood for in the following words: "Cornell associated practical education with liberal. It ranked professional training among its functions; and it enlarged the notion of learned or scientific professions so as to include, along with the traditional trio of law, medicine and theology, such modern vocations as engineering, architecture, veterinary medicine and agriculture. Whatever calling rested on science or scholarship, that was a proper subject for university instruction. In this respect Cornell University simply did for the nineteenth century what the universities of Salerno, Bologna, Paris and Oxford had done for the twelfth and thirteenth centuries. "Cornell," said a great English educator — Principal Fairbain of Mansfield College, Oxford — "is an example of a university adapted to the soil, bravely modern and industrial without ceasing to be ancient and classical or philosophical and historical." In 1882 the total number of regularly matriculated students in Cornell University was 384 and in 1922 the number was 5754, to which should also be added 1937 for the Summer Session of that year.

After the treaty of 1898, when Spain ceded the Philippine Islands to the United States, the policy of our government towards the Filipinos was hampered by great lack of knowledge of the situation. To meet this difficulty in part, President McKinley appointed in January, 1899, a first Philippine Commission, with Dr. Schurman at its head. Describing the

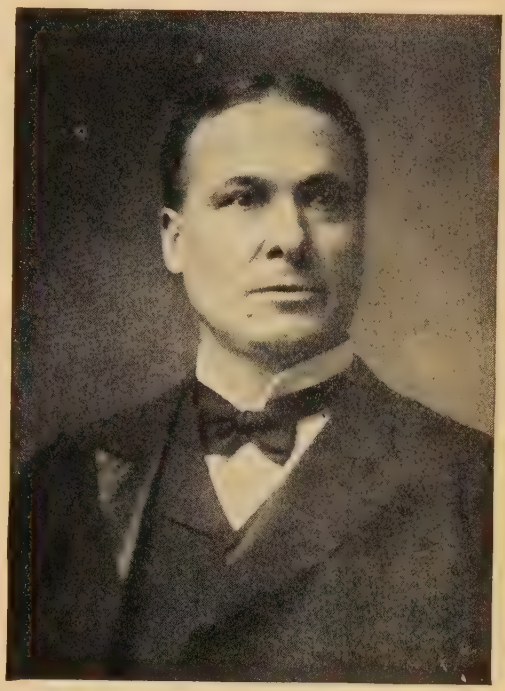
interview in which he accepted the presidency of the commission, Dr. Schurman says, "The President . . . desired to know whether I would accept the presidency of the commission. I replied that I feared it would be difficult, perhaps impracticable, for me to get away from Cornell University . . . but even if a leave of temporary absence could be secured (and the president said he would send a message to the board of trustees), there was, I observed, another obstacle that might prove irremovable. 'To be plain, Mr. President,' I continued, 'I am opposed to your Philippine policy: I never wanted the Philippine Islands.' 'Oh,' replied the President, 'that need not trouble you; I didn't want the Philippine Islands, either; and in the protocol to the treaty I left myself free not to take them; but — in the end there was no alternative.'"

In March, 1899, the commission began its work and devoted itself chiefly to conciliating prominent Filipinos and to building up a party favorable to America. When he returned to America, President Schurman lost no opportunity of advocating a lofty and disinterested policy to be pursued towards the Filipinos, and strongly condemned any exploitation of the Philippines by the home government. The rice fields, sugar estates, the tobacco plantations, the hemp farms, are the property of individual Filipinos. "All the natural resources — land, minerals, forests, fish, etc., — belong thus to the inhabitants of the islands," he writes, and he points out the danger of attempting to Americanize the Filipino who is of Malayan stock "and can only be civilized in the line of his own civilization, such as it is".

Dr. Schurman is the author of "Kantian Ethics and the Ethics of Evolution"; "The Ethical Import of Darwinism"; "Agnosticism and Religion"; "Report (to Congress) of the First Philippine Commission" (joint author of 4 vols.); "Philippine Affairs — A Retrospect and Outlook"; "The Balkan Wars, 1912–13"; "Why America Is in the War", etc. He has also been a frequent contributor to the magazines, and has delivered many addresses on public questions in all parts of the country.

JOSIAH WEDGWOOD
The King of English Potters

JOSIAH WEDGWOOD, the most famous of English potters, was born near Burslem, Staffordshire, the center of the pottery industry, of a family long identified with it, and was baptized in the parish church there on July 12, 1730. He had no schooling after he was eight years, but was apprenticed to his elder brother, Thomas, who was not altogether enamored of the youngster's passion for experiment and original design and methods, so that, at the comple-

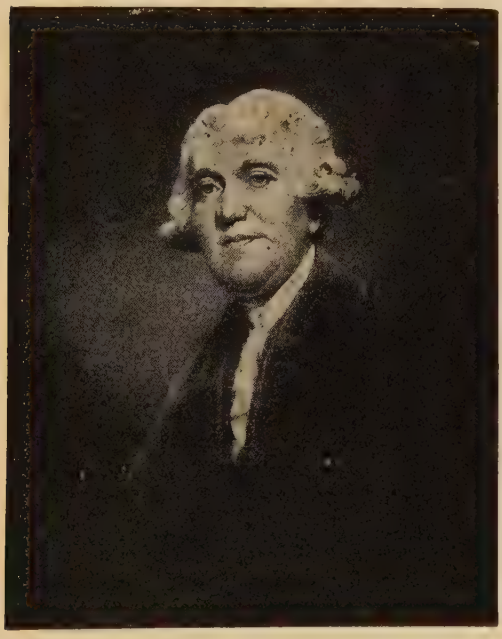


JACOB GOULD SCHURMAN

tion of his term of service, Josiah was glad to transfer himself to the service of outsiders. Living frugally and studying hard, Wedgwood felt justified, when he was about twenty-eight, in setting up a little establishment of his own.

He was now free to experiment as he would. He yearned to better the processes which he had been compelled in the main to follow. In order to do so he had to revolutionize workshop practice, to insist upon cleanliness and order, to demand exactness of work, to teach his men to be artistic potters instead of mere thumpers of wet

clay. It was a great triumph for him when he was able to produce wares in which lids fitted, spouts poured and handles could be held. But he was striving for a better type of ware than any yet known to England, and the story of his efforts reads like a modification of that of Bernard Palissy. In essaying the improvement of the ordinary cream-colored ware, he considered with minute attention every detail of the body, glaze, form and ornament. There have been few happy accidents in the history of pottery, and Wedgwood found himself baffled again and again. The ordinary goods that he sold were so much better



JOSIAH WEDGWOOD

than those of his neighbors that he could have made a very comfortable living without further improvement, but the artist was stronger in him than the instinct of commerce. He worried on through trial after trial, doggedly persevering in face of every failure. One kiln after another was pulled down, his biographer tells us, in order to correct some defect or effect some necessary improvement. His losses from this source alone were at this time very heavy, and the ware itself was frequently destroyed before he could bring his firing processes to the right temperature necessary to secure the adequate result. His chemical combinations often completely puzzled him, and his experiments, both in body and in glaze, would, after the greatest care had been expended in their preparation, turn out utter failures. He had to invent, or, failing that, to improve, every tool, instrument and apparatus, and to seek for blacksmiths and mechanics to work under his guidance. He often passed the whole day at the bench beside his men, and in many cases instructed them individually.

Unwearied and indomitable in spirit, he persevered, and success came, complete and abundant. The famous cream ware, lighter, brighter and more beautiful than any pottery ever before made in England, was his, and the artist, without sacrificing one whit of his love for his art, became a factor, and a phenomenally successful factor. There was a ready market for his products in America and on the Continent as well as at home. The success of the Wedgwood ware was helped by his appointment as royal potter to Queen Caroline, through whose patronage it became known as "Queen's ware". The inventor had a shrewd suspicion that its phenomenal success was not wholly due to its intrinsic merit, for he wrote of it to Thomas Bentley, whom he had taken into partnership: "It is really amazing how rapidly the use has spread almost over the whole globe, and how universally it is liked. How much of this general use and estimation is owing to the mode of its introduction, and how much to its real utility and beauty, are questions in which we may be a good deal interested for the government of our future conduct; for, if a royal or noble introduction be as necessary as beauty to the sale of an article of luxury, then the manufacturer, if he consults his own interests, will bestow as much pains in gaining the favor of these advantages as he would in bestowing the latter."

As against this exposition of worldly wisdom, let us glance at the more ideal aspirations animating Wedgwood in the pursuit of his calling. He writes, also to Bentley, in proposing the partnership to him: "If you think you could really fall in love with and make a mistress of this new business, as I have done, I should have little

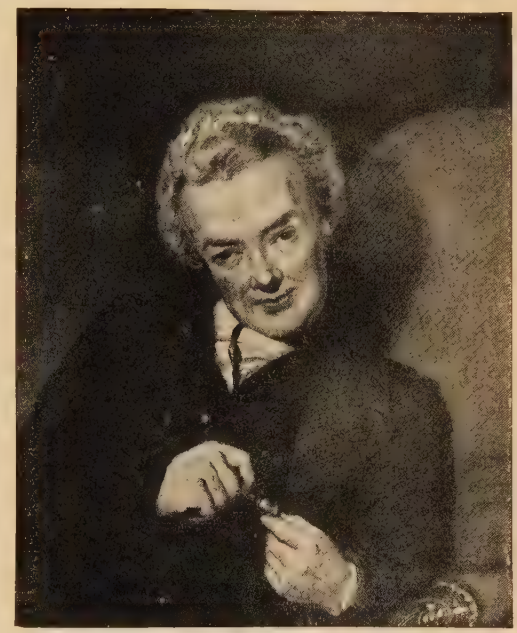
or no doubt of your success; for, if we consider the great variety of colors in our raw materials, the infinite ductility of clay and that we have universal beauty to copy, we have certainly the fairest prospect of enlarging this branch of manufacture to our wishes; and, as genius will not be wanting, I am firmly persuaded that our profits will be in proportion to our application. I am as confident that it would be, beyond comparison, more congenial and delightful to every particle of matter, sense, and spirit in your composition to be the creator, as it were, of beauty rather than merely the vehicle or medium to convey it from one hand to another."

It is unnecessary to follow Wedgwood through all the details of the career which now opened out to him; these belong of right to the history of ceramics, and may be found in another chapter of the present work. It is but just to say that he embellished and, indeed, revolutionized every branch of pottery and earthenware manufacture in which he engaged. He took a large share in the industrial development of Staffordshire. His own works at Etruria became a center of industry from which the fame of English pottery was carried to all parts of the civilized globe. Wedgwood's prosperity enabled him to speak with authority upon such matters as the internal communications of his native county; and the building of the Grand Junction Canal, uniting the Mersey, the Trent and the Severn, was largely brought about by his sage counsel, while he himself was able, at thirty-five, to contribute generously to the making of roads, as well as to the founding of a second free school at Burslem.

Wedgwood died at his home, Etruria Hall, on January 3, 1795, leaving a fortune of half a million pounds, fairly earned, as his epitaph records, by means which "converted a rude and inconsiderable manufactory into an elegant art and an important part of national commerce". Married when thirty-four, he became the father of three sons and four daughters. The eldest daughter became the mother of Charles Darwin. Emma, granddaughter of Josiah, became the great naturalist's wife.

WILLIAM WILBERFORCE
The Great Emancipator

WILLIAM WILBERFORCE, the English statesman and philanthropist, was born at Hull on August 24, 1759, the son of a wealthy old Yorkshire house, and after a career at Cambridge, in a "port and prejudice" atmosphere, where tutors and fellows did their best to make him a lazy, conceited prig, was plunged, by family influence, into a life of idle gayety. "If Billy turns Methodist he shall not have a sixpence of mine," his grandfather had said, when noticing a serious trend in the young



WILLIAM WILBERFORCE

man's disposition. "Billy" did not turn Methodist exactly, but as member of parliament for Hull, and afterwards for the county of Yorkshire, he found leisure to travel with the very man whom his grandfather had singled out for the purpose. This was Isaac Milner, who had been one of his early tutors. With Milner, Wilberforce, who from early boyhood had been without a father's care, made a close study of religion, and at twenty-five he had definitely chosen his course in life; he began a crusade for morality and for mercy and justice to his generation. It cannot be said that it was at this time that he first turned

his thoughts to the horrors of slavery, for when only fourteen he had written a letter on the subject to a York newspaper.

The iniquity and barbarity of the system were troubling the minds of many men. Details of the steps leading to the campaign against this blot on the fame of white men will be found in the life of William Clarkson. Even a cotton planter of the South, the home of slavery, would hardly defend it today, but a marvelous change has been wrought in public opinion within the last century and a quarter.

When Wilberforce was born, slavery was sanctioned by use and wont here and in England. Not until the emancipator was thirteen years of age was it determined that slavery could not exist in Great Britain. It is one of the few cases where judge-made law has been satisfactorily substituted for parliamentary enactment. Legally, the decision was bad; morally, it was superb. The decision was nobly defined in an immortal sentence of Curran's: "The spirit of the British law is that liberty is inseparable from British soil; that no matter in what language the man's doom may have been pronounced, no matter what complexion, incompatible with freedom, an African or an Indian sun may have burnt upon him, no matter in what disastrous battle his liberties may have been cloven down, no matter with what solemnities he may have been devoted upon the altar of slavery, the first moment he touches the sacred soil of Britain, the altar and the god sink together in the dust." The decision merely gave judicial sanction to the desires of the highest public opinion; it did not really express the existing law.

For slavery *was* sanctioned in England; it was a part of the national system. The land had never been wholly free from it. After the Norman Conquest the distinct slave class ceased as such to exist, and was merged with the lower order of ceorls into the general body of villeins. And slavery had never been abolished by act of parliament. The decision in question was therefore the noblest example of bad law that any courts could have given. But it left untouched, of course, the scandal of the slave-trade. That was officially recognized. From the time of Queen Elizabeth forward it had been a lucrative employment for the men who went down to the sea in ships. The great "advantage" conferred upon England by the Treaty of Utrecht was the bestowal upon that country of the exclusive right to supply slaves to the Spanish and Portuguese possessions.

When Wilberforce came out upon the question he was flying in the face of his sovereign. The wretched George III had caused a letter to be written to the governor of Virginia directing that that official should not, "upon pain of the highest displeasure", assent to any law by which the importation of slaves should be in the least altered or limited. The fatuous old king had the selfish support of all the "interests". All the great English mercantile houses were more or less implicated in the traffic, and many noble families profited directly or indirectly from it. They or their kin had plantations in the West depending for their prosperity upon the miserable labor of their human beasts of burden.

The history of a preceding age makes curious reading — Gladstone defending the slave-trade; Shaftesbury passionately opposing every human right that the Reform Bill proposed; Peel and Bright exerting their influence and oratory to the end that the factory-owner and the mine-owner might maintain their sacred right to treat their employees a little worse than the meanest of their cattle; Sir Joseph Banks ridiculing the steamship; Palmerston forbidding the building of the Suez Canal; savants of the Royal Society sneering wireless telegraphy back into its cradle. We do well, at times, to question the judgment of our leaders. Wilberforce did not question it; he fought it with all his strength.

He began by agitating, not for the abolition of slavery, but for much less. Through ill health he had to get Pitt to move a resolution for him pledging the House of Commons to inquire into the whole question of the traffic. The next step was to lead a number of public men down to the Thames to inspect a slave-ship fitting out, and these, having seen the mere vessel, induced the House of Commons to pass a bill limiting the number of slaves

a ship might carry. Even that slight concession was bitterly opposed by the vested interests, but it was a valuable gain, for it marked the first step towards the great goal sought. It established a principle.

Reform was opposed at every stage on the most insincere and callous pleas. At first its opponents said that if England abandoned the traffic, then France would monopolize it, and attain commercial preeminence. When the French republic denounced the traffic, anti-abolitionists held up their hands in horror: "What! Adopt a scheme which would associate our country with the infamous ruffians of the French Revolution!" they said. As the battle progressed, conditions for a time grew worse, instead of better. England was gaining new colonial territories in her wars, and African slaves were much in demand. The first material advance was gained in 1805, however, when, by an Order in Council, the traffic with newly acquired colonies was prohibited. This was followed in the next year by an act making it unlawful for a British subject to trade anywhere in slaves, except as regards the original British colonies. In 1807 the traffic was totally abolished, and successive acts made the crime punishable, first by fine, then by imprisonment, next by death and finally by transportation. Nineteen years' labor had gone to the securing of this reform, and what did all the gains mean? Simply that Britons were no longer allowed to capture or acquire their fellow-creatures and sell them as slaves. The actual slavery itself was left untouched.

The work had broken Wilberforce's health, and had nearly ruined him. One election, fought against powerful vested interests, cost him £30,000, and his supporters a further £70,000, while the unsuccessful candidate, a slave-owner, spent £500,000. But having gone so far with their object, Wilberforce and his friends went forward with the question of the abolition of slavery itself, and in sixteen years they achieved this reform — that a government circular was issued to the West Indian settlers to the effect that they should no longer flog women, and that the use of the whip in the fields must be discontinued.

The colonists at once threatened to cut themselves out of the Empire and make themselves independent! In Demerara an English missionary, who had sought merely to civilize the slaves, was tried by court-martial and allowed to die in prison. The planters complained that he had "addressed a promiscuous audience of black or colored people as 'my brethren and sisters'"! John Smith's martyrdom probably did as much for the emancipation of British slaves as John Brown's did for our own. Wilberforce labored till the end for the work to which he had given his life. He was absolutely absorbed in it, so that even his own children did not know him, and fled at his approach. "They are frightened of strangers", their nurse told him. During the last twelve years of his life he sat in parliament for a smaller constituency than that to which he had been accustomed, and before his death he gained the crown he deserved. It was the announcement that an act had been passed emancipating the slaves throughout the British dominions.

Wilberforce died in London on July 29, 1833, and was buried in Westminster Abbey. "Few men," said Lord Brougham, "have ever either reached a higher and more enviable plane in the esteem of their fellow-creatures, or have better deserved the place, than Wilberforce, whose genius was elevated by his virtues and exalted by his piety."

FRIEDRICH WÖHLER
One of the Founders of Organic Chemistry

FRIEDRICH WÖHLER, one of the founders of organic chemistry, was born in 1800 at Escherheim near Frankfort-on-the-Main, Germany. He studied medicine and chemistry at Marburg and Heidelberg and subsequently worked under the direction of Berzelius at Stockholm, where he started a lifelong friendship with the Swedish chemist. Another close friendship made at this time with Liebig resulted in a number of joint researches and important experiments, especially those on the oil of bitter almonds, on the radicle benzoyl and on uric acid. In 1825 he became teacher of chemistry in the industrial school then newly established in Berlin

where he remained till 1831; at that date he received a similar appointment in Cassel. He was appointed to the chair of chemistry in the medical department of the University of Göttingen, and inspector-general of the pharmacies of the kingdom of Hanover in 1836, posts which he held till his death on the 23rd of September, 1882.

As a teacher Wöhler was brilliant and many-sided, but it is his original work that has connected his name with the most important discoveries in the early history of organic chemistry. He broke down the barrier that until 1828 had existed between organic and inorganic chemistry, by the synthesis of urea — the first organic compound produced by artificial laboratory means without the agency of life. In inorganic chemistry, by reducing in potassium the chloride in aluminium he obtained metallic aluminium as a fine powder, and by the same method metallic beryllium and yttrium. He founded the nickel industry by devising a process of manufacturing pure nickel on a large scale, and in the course of his long laboratory practice worked out methods of exact analysis.

He published *Grundriss der anorganischen Chemie* (1831), *Grundriss der organischen Chemie* (1840), *Die Mineralanalyse in Beispielin* (1861 and many subsequent editions, and translated into various languages).

WILBUR AND ORVILLE WRIGHT
The First Men to Fly

WILBUR and ORVILLE WRIGHT must be considered jointly, for each so sympathetically complemented the work of the other that the results cannot be judged apart. Wilbur Wright was the son of Milton Wright, and was born at Millville, Indiana, on April 16, 1867, his brother Orville being born in 1871. The father was an itinerant preacher, who became a bishop of the religious organization known as the United Brethren in Christ. The two boys were educated in the schools of Richmond, Ind., and Dayton, Ohio, where their parents eventually settled. They had no scientific training, no workshop experience, save that acquired in their own premises. They began their career in partnership as job printers, and from that drifted into business, in quite the smallest way, as bicycle repairers.

No one would have dreamed that a revolution in locomotion was to have their modest workshop as a cradle. From 1903 on they began to experiment with problems as to artificial flight. With Teutonic thoroughness they mastered all the knowledge that was to be gained by reading of what had been done in the same field by others, and with characteristic American initiative they applied their knowledge, supplemented by entirely new ideas of their own, to the production of an aircraft unlike anything that had previously been produced. Other men were experimenting in the same field, but more with a view to dirigible airships. The Wrights aimed at a heavier-than-air machine, to be driven by the new, light motor-engines. The idea of the heavier-than-air machine itself was not a novelty, for Sir Hiram Maxim had already sought the same end with an airplane fitted with a powerful steam engine. The Wrights were the first to adapt the internal-combustion engine to the purpose; to drive by such an engine a light skeletonized structure, supported by wings fashioned on the plan of the pinions of a bird.

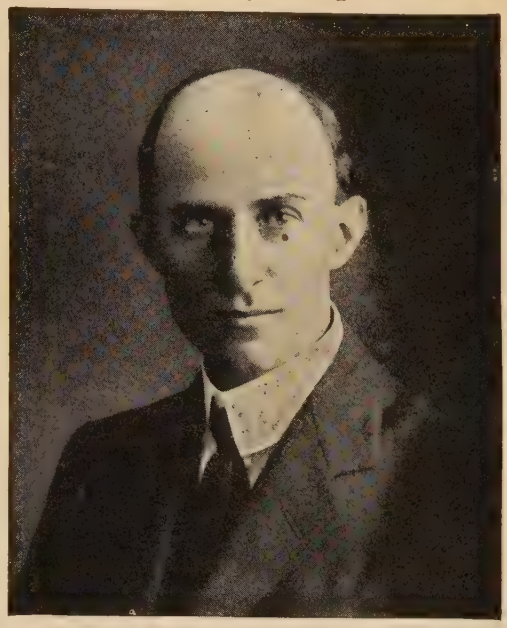
Reference to the chapter on aërial flight will reveal the steps by which aëronauts had been led to acceptance of this principle. But the Wrights did not step into a machine modeled without difficulty upon plans perfected by their dead predecessors. Even M. Santos-Dumont, after his successful journey by dirigible round the Eiffel Tower, genially ridiculed the notion of flight to be achieved by a machine modeled on the structure of a bird's wings. "Would you believe it?" he laughed; "I have a friend who is actually studying the wings of all the birds he can get hold of, in the belief that he will be able to introduce the idea of a bird's wing into a heavier-than-air machine!" But although M. Santos-Dumont did not know it, these two young American bicycle mechanics were at that very time attempting the supposedly impossible thing. They worked at their plan with extraordinary patience and zeal — and good fortune. Month after month they experimented with various forms of gliding

machines, which were little better than glorified box-kites. Funds ran low, but they sacrificed all they dared to continue their work, aided by their father, to the best of his ability, and their sister from her scanty savings as a teacher.

At last they had learned all that was to be known from the gliding machine. They mastered the secret of balancing by devising adjustable wings on lines already explained. Ultimately they risked the great adventure; they yoked to their glider a little motor-engine made by themselves, and on December 17, 1903, flew for fifty-nine seconds! In the following year the airplane made a hundred short flights, and in 1905 on six occasions they accomplished air-trips of over ten miles, and twice exceeded twenty miles at a stretch. As far as possible they kept their trials secret. They flew out in the wilds on the coast of North Carolina, and for long nobody outside the Wright family knew anything of what was doing. Then the story began to leak out that two mad bicycle repairers were flying in America. When Wilbur Wright set out for Europe, in July, 1908, with one of his machines, there was considerable skepticism as to his abilities to rise aloft. He established himself in a little shed in a field, first at Autours, near Le Mans, and later at Pau, and prepared to prove their case.

"All day long the crowds gathered about the huge wooden sheds with the great doors. From morning till night they waited in the fields; and as the days went by and nothing happened, the peasants began to scoff and jeer. And then one day the doors of the wooden house swung open, and out came Wilbur Wright, out came Orville Wright and out came an ungainly machine which is very familiar now, but was something to laugh at then — a huge thing of wood and canvas, of wires and bars and levers, running along the ground on wheels. And the peasants laughed more than ever. This, then, was the thing they had waited weeks to see. As the machine was run into the middle of the field the peasants jeered more than ever. But Wilbur Wright cared nothing at all. He sat down in his seat and made ready. 'One!' he shouted. 'One!' jeered the crowd. 'Two!' he shouted. 'Two!' jeered the crowd. 'Three!' he shouted, and the crowd jeered no more, for Wilbur Wright was flying. He came down from the clouds never to be jeered at again, for these people, belonging to the most emotional race in the world, fell on his neck and kissed him. They had seen a new chapter open in the history of mankind; they had seen the first man fly."

The subsequent progress of the Wrights — mainly constructional — is part of the history of aërial navigation. Wilbur Wright died in his bed, a remarkable circumstance considering the risk he ran and the terrible mortality among the devotees



WILBUR WRIGHT
Portrait by Russell & Sons.

of the science of which he and his brother were the pioneers. He died at his home in Dayton, from the effects of typhoid fever, on May 30, 1912.

Orville Wright, who with his brother, was the first to fly in a heavier-than-air machine, and with him, invented the system of control used in all flying machines of today, survived his brother and remained as director of the Wright Aëronautical Laboratory at Dayton. He was awarded gold medals by Congress and various states and foreign kingdoms and was made Chevalier of the Legion of Honor.

THE VIOLENCE OF VESUVIUS: A RAGING STORM OF FIRE FROM THE DEPTHS OF THE EARTH

SUCH A SIGHT AS THIS IT WAS THAT POMPEII LOOKED UPON; SUCH A SIGHT IT IS THAT EVEN NOW IS SOMETIMES SEEN ACROSS THE BAY OF NAPLES

VOLCANIC CATASTROPHES

The Story of the Great Historic Surprises from Vesuvius, Bandai-san, Krakatoa, Mont Pelée and Mauna Loa

SCENES WHEN FIRE RAINED FROM THE SKY

IN the last chapter we described the general phenomena of volcanic eruptions; we will now give brief accounts of some of the great volcanic catastrophes.

One of the most notable eruptions of historical times was the terrible outburst of Vesuvius in 79 A.D. — the eruption that buried the great cities of Pompeii and Herculaneum. For centuries the monster had slumbered. A hundred and fifty years before the great eruption, the gladiator Spartacus, with seventy followers, took refuge in its crater, and, when besieged by the prætor Claudius Pulcher, escaped by climbing down with the aid of ropes made of vine branches. No one thought of the mountain as a volcano, unless, perhaps, a few observant men, such as the historians Strabo and Diodorus Siculus, who noticed the cindery aspect of the surrounding country. Up almost to the crater of the volcano were fields, vineyards, orange groves and prosperous villages, and at its base were the cities Herculaneum and Pompeii, with their villas and palaces, their theaters and temples. No dread of eruptions disturbed the inhabitants of this happy land, which basked in the sun and "laughed fertility". Yet they had many warnings before the disaster. The monster stirred in his sleep; his great flanks heaved; the land was shaken again and again. For sixteen years this went on, until, finally, a violent shock, on August 24, 79 A.D., was followed by the great eruption.

The historical documents describing the eruption are, of course, the famous letters of the younger Pliny, and we cannot do better than quote part of one to Tacitus.

"Being got at a convenient distance from the houses, we stood still in the midst of a most dangerous and dreadful scene. The chariots which we had ordered to be drawn out were so agitated backwards and forwards, though upon the most level ground, that we could not keep them steady, even by supporting them with large stones. The sea seemed to roll back upon itself, and to be driven from its banks by the convulsive motion of the earth. It is certain at least the shore was considerably enlarged, and many sea animals were left upon it. On the other side a black and dreadful cloud bursting with an igneous serpentine vapor darted out a long train of fire, resembling flashes of lightning but much larger. . . . The ashes now began to fall upon us, though in no great quantity. I turned my head, and observed behind us a thick smoke, which came rolling after us like a torrent.

"I proposed, while we yet had any light, to turn out of the high-road, lest we should be pressed to death in the dark by the crowd that followed us. We had scarce stepped out of the path when darkness overspread us, not like that of a cloudy night, or when there is no moon, but of a room when it is shut up and all the lights extinct. Nothing then was to be heard but the shrieks of women, the screams of children, and the cries of men; some calling for their children, others for their parents, others for their husbands, and only distinguishing each other by their voices; one lamenting his own fate, another that of his family; some wishing to die from the very fear of dying; some lifting their hands to the gods, but the greater part

imagining that the last and eternal night was come which was to destroy the gods and the world together. Among them were some who augmented the real terrors by imaginary ones, and made the frightened multitude falsely believe that Misenum was actually in flames.

"At length a glimmering light appeared, which we imagined to be rather the forerunner of an approaching burst of flame, as in truth it was, than the return of day. However, the fire fell at a distance from us, then again we were immersed in thick darkness, and a heavy shower of ashes rained upon us, which we were obliged every now and then to shake off, otherwise we should have been crushed and buried in the heap.

"I might boast that during this scene of horror not a sigh or expression of fear escaped from me, had not my support been founded in that miserable though strong consolation that all mankind were involved in the same calamity, and that I imagined I was perishing with the world itself.

LAVA ADVANCING DOWN A VILLAGE STREET

"At last this dreadful darkness was dissipated by degrees, like a cloud of smoke; the real day returned, and soon the sun appeared, though very faintly, and as when an eclipse is coming on. Every object that presented itself to our eyes — which were extremely weakened — seemed changed, being covered over with white ashes, as with a deep snow."

This is a picturesque and interesting narrative, but strangely enough Pliny does not mention the destruction of Pompeii and Herculaneum which occurred during the very hours he describes. Pompeii was buried beneath layers of ashes, cinders and stones, in some places sixty or seventy feet deep. Herculaneum was drowned in volcanic mud. So deeply and completely were these cities buried that during the Middle Ages their very existence was forgotten. It was one of the most terrible catastrophes in human history.

After that great eruption Vesuvius was in an explosive state for many years, but in the seventeenth century it seemed quite dead, and cattle grazed and wild boars had their den within its crater. Again it proved active; six months of earthquakes in 1631 were succeeded by a terrific eruption, which blew away the whole top of the mountain and scattered ashes for hundreds of miles. Seven streams of lava poured from the crater, destroying several villages, among them Resina, which had been built over the buried Herculaneum. For the next hundred and fifty years there were many eruptions great and small, and the mountain underwent frequent alterations in shape and size. In 1794 a great fissure was formed nearly half a mile long, and a tremendous torrent of lava ran down to the sea. All through the nineteenth century periodic earthquakes and volcanic paroxysms continued. Altogether, in the eighteenth and nineteenth centuries, Vesuvius was in eruption about fifty times, or about once every two years.

Within quite recent times there have been two great eruptions, one in 1872 and one in 1906. That of 1872 was carefully observed by Professor Palmieri. In all respects it was typical. It was preceded for some time by earthquake shocks and increased volcanic activity; and then suddenly, on April 24, the eruption began. On this occasion the column of vapor rose to a height of about 20,000 feet, and masses of soft lava, known as "volcanic bombs", were thrown up over 4000 feet

PRESERVED INTACT FOR CENTURIES UNDER THE ASHES FROM VESUVIUS

A CANTEEN, OR WINE BAR, WITH ALL ITS FITTINGS AND UTENSILS, DISCOVERED BY THE EXCAVATORS OF POMPEII

above the mouth of the crater. Great streams of lava poured down the mountain, and lava oozed from numerous fissures in the cone, so that Palmieri described it as sweating fire. The lightning flashes in the vapor column were very vivid, and the bellowing and roaring of the explosion could be heard miles away. Several villages were partially destroyed, but most of the inhabitants escaped.

In April, 1906, Vesuvius was in eruption again, and six lava streams poured down the mountains. Professor Matteuci, then in charge of the Vesuvius Observatory, reported on April 8: "The eruption of Vesuvius has assumed extraordinary pro-

STROMBOLI AWAKE

portions. Yesterday and last night the activity of the crater was terrific, and is increasing. The neighborhood of the observatory is completely covered with lava. Incandescent rocks are being thrown up by the thousands to a height of 2400 or even 3000 feet, and, falling back, form a large cone. Another stream of lava has appeared. . . . The noise of the explosion and of the rocks striking together is deafening. The ground is shaken by strong and continuous seismic movements, and the seismic instruments threaten to break."

On April 9 he reported that: "The explosive activity of Vesuvius, which was so great yesterday, and was accompanied by very powerful electric discharges, diminished yesterday afternoon. During the night the expulsions of rocks ceased, but the emission of sand increased, completely enveloping me, and forming a red mass from 6 to 10 centimeters deep, which carried desolation into these elevated regions. Masses of sand gliding along the earth created complete darkness till seven o'clock. Several blocks of stone broke windows in the observatory."

Much more sand and dust were discharged than during the previous eruption, and all the roofs of the houses in Naples were covered with a fine red dust. Vesuvius, therefore, has had a pretty violent past, and in the last few years there have been several great eruptions with copious lava flows.

Other well-known volcanoes in the Mediterranean are Etna, Stromboli, Santorin and Vulcano.

Bandai-san, or Kobandai-san, in Japan, is not so well known as Vesuvius, but this is not surprising, since, for at least a thousand years, it cultivated a masterful inactivity, and peasants worked daily in its green forests without the least foreboding of a fiery doom. Probably there had been small local upheavals during the intervening centuries, but nothing like a great eruption. Bandai-san, like Krakatoa, is really a group of peaks which are the remains of an ancient colossal volcano, and, according to tradition, the original massive mountain was split up by a great explosion which buried fifty villages; but so dormant had its volcanic energy been for ten centuries that at the time of the catastrophe a forest occupied the site of the ancient crater.

A terrific explosion took place on July 15, 1888. There were a few rumblings, a severe earthquake, and then suddenly a dense column of steam and dust shot into the air. Explosion followed explosion, darkness covered the land, lightning flashed, and then a mighty avalanche of mud, earth and rocks crashed down the mountainside, burying villages as it went, and devastating an area of 27 square miles. Isurumaki, a Japanese priest, who had a miraculous escape from death, gives the following interesting account of his

experiences: "The morning of the 15th, which was the fatal day, dawned with a bright and pleasant sky. . . . At about eight o'clock, however, there was a fierce convulsion of the ground, and we all rushed out of the house. In about ten minutes, while we were fearfully wondering what was the matter, a terrible explosion suddenly burst out from the slope of Kobandai, about a quarter of a mile above a place at which steam had been issuing from time immemorial. This was followed by a dense mass of black smoke, which ascended into the air, and immediately covered the sky. At this time showers of large and small stones were falling all about us. To these horrors were added thundering sounds, and the tearing of mountains and forests presented a most unearthly sight, which I shall never forget as long as I live. We fled in all directions, but before we had gone many yards we were all thrown prostrate to the ground. It was pitch dark; the earth was still heaving beneath us; our mouths, noses, eyes and ears were all stuffed with mud and ashes. We could neither cry out nor move. I hardly knew whether I was dead or in a dream. Presently a stone fell on my hand, and I knew that I was wounded. Imagining that death was at hand, I prayed to Buddha. Later I received wounds on my loin, right foot and back. After the lapse of an hour the stones ceased to rain, and the atmosphere had cleared from darkness to a light like moonlight. Thinking this a fine opportunity to escape, I got up and cried, 'Friends, follow me!' but nobody was there. When I had descended about half a mile, there was a second explosion, and a quarter of a mile further on a third explosion, and ashes were ejected, but no stones."

THE STEAMING SLOPES OF BANDAI-SAN, JAPAN

The most striking feature of this explosive eruption was the immense amount of earth and stones that was discharged, much of it coming down like a landslide. The mountain was simply pulverized. Part of it was hurled into the air, and part of it slid down like an avalanche of mud, earth and rocks, mainly earth and rocks, with here and there huge boulders. As is usual in volcanic explosions, a great quantity of dust was shot forth, and covered the country for miles around.

The enormous volume of solid matter strewn over the country amounted to nearly 1587 million cubic yards. It filled up all the ravines and gorges, engulfed all familiar landmarks, dammed up several rivers, converted twenty-seven square miles into a desert and buried four villages, and partly covered seven more. The loss of life, however, was comparatively small; only 461 persons were killed, including 92 who fled from a safe hamlet and were all struck down within a few yards. An interesting feature of the eruption was the terrible blast of air driven before the explosions of steam. Houses were leveled, and trees were torn up by the roots or stripped of leaves and branches and left standing bare as telegraph poles. Another interesting feature was the multitude of conical, basin-like holes made in the ground by falling stones.

The latest eruption of Krakatoa requires special mention, for it is probably the greatest explosive eruption in historical times. The volcano was situated on an island in the Sunda Strait, between Sumatra and Java, a strait connecting the China Seas with the Indian Ocean. This island, with several others, is the remnant of an ancient volcano which was probably about 10,000 feet high, and had a crater about 25 miles in circumference. For more than two hundred years the island had rested from its volcanic labors; it was covered with rich vegetation and dense forests. Then, in 1880, earthquakes began, and they were no slight tremors, for they were felt as far off as northern Australia. On May 20, 1883, the eruption proper began with sounds like the firing of artillery, which were loud enough to be heard a hundred miles away. Next day ashes were sprinkled on both sides of the straits. On May 26, a party from the mainland visited the islands, and found them covered with a white dust like snow, while a column of vapor 10,000 feet high was rising into the air, and scattering showers of dust and pumicestone. All through June, July and August this state of affairs continued, till finally, on August 26 and 27, the culmination of the eruption was reached.

A PHOTOGRAPH OF KRAKATOA TAKEN ON MAY 27, 1883
Reproduced from *The Eruption of Krakatoa*, by permission of the Royal Society.

The Sunda Straits are on the route of trading vessels, and captains and passengers of ships on the spot at the time have given us most information of the final catastrophe. Captain Wooldridge, of the *Sir R. Sale*, writes that on the 26th the sky presented "a most terrible appearance," and that the cloud above the mountain was like an immense pine, the stem and branches formed of volcanic lightning. After sunset the cloud looked like a "blood-red curtain with edges of all shades of yellow," and lightning zigzagged through it. Captain Watson, of the *Charles Bal*, tells of chains of fire that ascended into the sky, and of "balls of white fire" which continually rolled down the mountain. During the great outburst startling electrical phenomena occurred. A peculiar pinkish flame came from the clouds, and balls of fire studded the mastheads and yardarms of the two ships. The mainmast conductor of the *G. G. London*, fifty miles away, was struck by lightning six times, and "the mud rain which covered the masts, rigging and decks was phosphorescent, and on the former presented the appearance of St. Elmo's fire". The natives were so frightened by it, thinking it the work of evil spirits, that the Europeans were left to drive the machinery for themselves.

All day on August 27 the *Northam Castle* and three vessels mentioned were in pitch darkness, and under a continual rain of pumice-stone and dust. So violent were the explosions that they were heard three thousand miles away, and they caused some of the most tremendous air-waves that have ever been known. Windows were broken, walls cracked, lamps overthrown, gas-jets extinguished a hundred miles away and some air vibrations traveled several times round the globe. By the sudden dislodgment of immense volumes of rock below water, vast waves were sent sweeping over the adjacent shores of Java and Sumatra at the rate of nearly four hundred miles an hour, and towns and villages were destroyed, two lighthouses swept away, and nearly 40,000 people drowned.

The Rev. Phillip Neale, one of the few survivors of the town of Anjer, which was overwhelmed by the sea, gives the following interesting account of his escape. He says: "About six A.M. I was walking along the beach. There was no sign of the sun, as usual, and the sky had a dull, depressing look. Some of the darkness of the previous day had cleared off, but it was not very light even then. Looking out to sea, I noticed a dark, black object through the gloom traveling towards the shore. At first it seemed like a low range of hills rising out of the water, but I knew that there was nothing of the kind in that part of Sunda Strait. A second glance — and a very hurried one it was — convinced me that it was a lofty ridge of water many feet high, and, worse still, that it would break upon the coast near the town. There was no time to give any warning, and so I turned and ran for my life. My running days have long gone by, but you may be sure I did my best. In a few minutes I heard the water, with a loud roar, break upon the shore. Everything was engulfed. Another glance around showed the houses being swept away and the trees thrown down on every side. Breathless and exhausted, I still pressed on. As I heard the rushing waters behind me, I knew that it was a race for life. Struggling on, a few yards more brought me to some rising ground, and here the torrent of water overtook me. I gave up all for lost, as I saw with dismay how high the wave still was. I was soon taken off my feet, and borne inland by the force of the resistless mass. I remember nothing more till a violent blow aroused me. Some hard, firm substance seemed within my reach, and, clutching it, I found that I had gained a place of safety. The waters swept past, and I found myself clinging to a cocoanut palm-tree. Most of the trees near the town were uprooted and thrown down for miles, but this one, fortunately, had escaped, and myself with it.

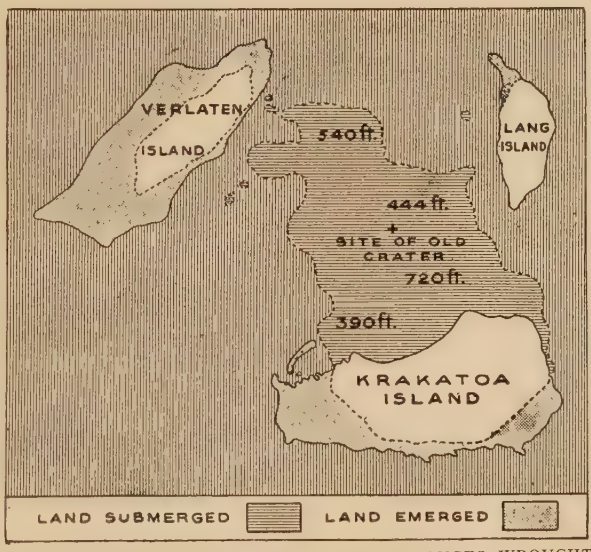


DIAGRAM ILLUSTRATING THE SURFACE CHANGES WROUGHT BY THE KRAKATOA ERUPTION

"The huge wave rolled on, gradually decreasing in height and strength until the mountain slopes at the back of Anjer were reached, and then, its fury spent, the water gradually receded and flowed back into the sea. The sight of those receding waters haunts me still. As I clung to the palm-tree, wet and exhausted, there floated past the dead bodies of many a friend and neighbor. Only a mere handful of the population escaped. Houses and streets were completely destroyed, and scarcely a trace remains of where the once busy, thriving town originally stood.

Unless you go yourself to see the ruin, you will never believe how completely the place has been swept away. Dead bodies, fallen trees, wrecked houses, an immense muddy morass and great pools of water are all that is left of the town."

The dust of the explosion is stated to have reached a height of 17 miles, and gave rise to marvelous sunsets and sunrises all over the world. The Hon. Rollo Russell described the sky at Cannes on January 10, 1884, as follows. "Orange ordinary glow in S. W. near horizon; above this a greenish-bluish white arc, then a beautiful yellow band; then, up to the zenith, a very beautiful lilac tint. All these colors were of extreme softness, and, though not so striking as some of the sunsets in December, in point of beauty they were quite unsurpassable and of superb magnificence in their further progress. The pink, purple or lilac now retired in the most steady and regular manner towards the horizon, and were visible to the end; thirty-five minutes after sunset the arc was formed of the inner part, which from steel-blue had gone through olive-green to yellow, the middle yellow, and the outer purple. Through the fringe of this Venus shone beautifully. The horizon — about a quarter of the circle — was deep yellow. The purple part being the smallest was flooded, except at the edge, by the orange light, which shone in a grand arc for a long time with great splendor, casting shadows. In about fifty-four minutes the primary glow was gone, having sunk in a deep red band. The eastern sky during the first part of the display was a glorious deep blue, then very dark purple-blue, and, lastly, only illumined by the silver moon."

A STEAMER CARRIED INLAND BY KRAKATOA'S SEA WAVE

Monsieur de Montessus wrote from San Salvador, in Central America: "The remarkable sunsets have been seen here since the last days of November, 1883. About half an hour after sunset, and an hour before sunrise, the horizon is gradually illuminated with a magnificent coppery-red tint, very constant in color, very intense, and lasting on the average twenty to twenty-five minutes. The moon, when circumstances allowed of it — that is, when her altitude did not exceed 15 degrees — was colored a magnificent emerald-green, and it was extremely beautiful to see it at the time of gray light, when its disc was of a pale green, with its crescent horn deep green in the midst of an immense crimson curtain. Venus only was able to penetrate the curtain, and was also green."

Not only were there green moons, but also blue and green suns. On September 12, 1883, a government official wrote from Ceylon: "The sun for the last three days rises in a splendid green, when visible — *i.e.*, about 10 degrees above the horizon. As he advances, he assumes a beautiful blue, and as he comes further on looks a brilliant blue resembling burning sulphur. When about 45 degrees it is not possible to look at him with the naked eye, but even when at the zenith the light is blue, varying from a pale blue to a light blue later on, somewhat similar to moonlight, even at midday. Then, as he declines, the sun assumes the same changes, but *vice versa*. The moon, now visible in the afternoons, looks also tinged with blue after sunset, and, as she declines, assumes a very fiery color 30 degrees from the zenith."

The Krakatoa eruption was certainly in some respects unique, but as a tragedy

KILAUEA VOLCANO, CONE NORTH OF HALEMAUMAU, HAWAII

Photo Neorihiro

The stream of viscous lava flowing from the crater forms blobs which cool first on the edges, pushing forward claws until they look like a mass of lobsters, — which indeed they are called — as shown in this picture loaned by Dr. T. A. Jaggor, Jr., Director of the Hawaiian Research Association.

THE RUINS OF ST. PIERRE, MARTINIQUE, AFTER THE BLIGHTING ERUPTION OF MONT PELÉE

ALL THAT WAS LEFT OF ST. PIERRE, THE PEARL OF THE LESSER ANTILLES—A TOWN OF 25,000 INHABITANTS

From a photograph by James Johnson, Esq., M.D.

it is not to be compared with the eruption of Mont Pelée, in 1902. The island of Martinique, on which Mont Pelée is situated, is one of the most beautiful of the West Indies, and St. Pierre, its chief town, was considered by Lafcadio Hearn "the quaintest, queerest, and the prettiest withal, among West Indian cities". The island was a tropical paradise basking in blue seas, and clad from head to foot in luxuriant vegetation. Even Mont Pelée, though its name signifies bald, was clothed in green, and the old crater on its summit had become a beautiful mountain lake surrounded by ferns and lobelia.

For some time before the disaster of 1902, Mont Pelée had been threatening danger. During all of April steam was seen issuing from a valley on the shoulder of the mountain, and on the 25th there was a slight discharge of ashes, and an exploring party found that an old lake bed was filled with water. On the 30th there were earth tremblings and slight explosions. All these were warnings of impending danger, but the light-hearted inhabitants had little fear, and their chief paper, *Les Colonies*, advertised an excursion to the summit of the mountain on May 4, "if the weather be fine".

On May 2, however, there was a violent eruption with loud explosions, and heavy clouds of condensed steam so that the people began to take alarm, and schools and stores were closed. Soon the streets and gardens were white with falling ashes, and birds dropped dead, killed by noxious gases. Nothing disastrous to human life happened, however, till the 5th, when the side of the new lake was blown out, and its water, rushing down the side of the mountain, carried away trees and rocks, destroyed with a river of mud a big sugar-mill and thirty persons in it, and finally plunged into the sea with such momentum that it raised a huge wave that sunk two yachts, and flooded the lower streets of St. Pierre. Then the alarm of the people grew to a panic, and crowds fled from the town to Fort de France. "It was a flight for safety," says *Les Colonies*, "without knowing where to turn."

The few moments that changed a busy town to a cinder

But the crowds did not flee too soon; death was at their heels. At 7:50 on the morning of May 8, the mountain exploded with deafening detonations, and a fiery cloud of intensely hot gases and incandescent particles of rock rolled down upon St. Pierre. In a few moments the town was ablaze, and soon thirty thousand bodies lay dead. Captain Freeman, of the *Roddam*, who watched the terrible tragedy from the sea, saw a few forms running distractedly upon the beach, but death soon caught them, and the "quaintest, queerest and prettiest of West Indian cities" was a city of the dead — a blazing, thundering charnel-house. Torrential rains followed the eruption, and, as Heilprin puts it, "At the end of this time the city was laid in smoldering ruins, coated with ash-paste, and looking as if built of adobe plaster. What had before been the vivid coloring of houses of the tropics was now an ashen gray — the color of earth, cold, bleak and burned."

So thoroughly had death done its work that only one man in the whole city survived, a negro prisoner in the city jail.

The strange fate that left alive one criminal negro

He said that when he was waiting for breakfast, on the morning of May 8, hot air, mixed with ashes, suddenly came through the grating and scorched him. The intense heat lasted only for a moment, and left him fearfully burned. For three days he lay undiscovered, but on the fourth he was heard calling for help, and was liberated. It was certainly an amazing escape. "There perished in St. Pierre the governor of the colony and his wife; Colonel Gerbault, chief of artillery, and his wife; the British and American consuls and their families; twenty-four priests; seventy-one sisters belonging to various Catholic orders; all the professors of the Lycée except five; all the members of the scientific volcano commission except one; and there survived — one criminal negro!"

NOT A MOUNTAIN BUT A CUP-LIKE DEPRESSION IN AN EXTENSIVE PLAIN

Courtesy Geological Museum of Harvard University

KILAUEA CRATER FROM THE SOUTH, SHOWING THE FIRE-PIT IN THE FOREGROUND

A blast that scorched the shipping from the waters

No one knows exactly the nature of the cloud that wrought such havoc, but it certainly was hot gas, probably ejected towards the town under tremendous pressure and with a velocity of over 40 miles an hour. It not only slew as it went, but it tore solid houses to pieces "as children's playhouses of kindergarten blocks would be torn to pieces by the discharge of a thirteen-inch gun"; it uprooted great trees; it dismounted heavy guns; it tossed about heavy boulders and colossal statues. Many authorities hold that it was probably a blast of superheated steam, but it may have also contained poisonous gases. Whatever its nature, its force was terrific, its effects devastating.

A second blast of the same nature occurred on May 20, and completed the work of destruction, so much so that "it was impossible to determine whether a particular heap of stones, plaster and debris had been a store, a warehouse, a public building or a private residence". Not only was the town of St. Pierre demolished in this way, but the blast rushed out to sea and capsized and totally wrecked all the vessels in the roadstead except two — the *Roddam* and the *Roraima*. The former parted anchor, and eventually reached St. Lucia with twelve of her officers and men dead and ten others severely burned. The *Roraima* had her masts, funnel, bridge and boats carried away, her decks were swept with stones, pumice and hot ashes, and she was set on fire. Only two of her passengers survived, and twenty-eight out of her crew of forty-seven died from burns and shock. Such, then, was the tragedy of Mont Pelée — one of the most terrible since the world began.

The largest crater of any of the technically active volcanoes in the world

When treating of the Islands of the Main we called attention to the fact that the Hawaiian Islands are of volcanic origin and really volcanic peaks. A few of these Pacific volcanoes deserve special mention. On the island of Maui is Haleakala, 10,000 feet high, with a tremendous crater 8 miles in diameter and 3000 feet deep. According to Dr. Jaggar, Director of the Hawaiian Volcano Observatory, "Haleakala is probably the largest of all craters among volcanoes that are technically known as active." The island of Hawaii itself is a mass of outpoured lava topped by several cones, some of them active, especially the king of volcanoes Mauna Loa or the Great Mountain. It measures nearly 200 miles in circumference at the base and its highest crater, Mokuaweoweo is 13,700 feet above sea level. Though Haleakala has a larger crater Mauna Loa is the greater volcano and ranks as the largest active volcano in the world with eruptions about every ten years. Dr. Jaggar states that "during the last century it has poured out more lava than any other volcano on the globe." The Hawaiian lava is very thin and when it flows over the crater rim or breaks through its side, "it runs in cascades of fiery red fluid rock". The first recorded eruption of Mauna Loa took place in 1823; this and the many succeeding outbreaks consisted mainly in the quiet discharge of enormous flows of lava. In 1855 a lava torrent three miles wide rushed down the mountain, spread out on the plain into a lake seven miles in diameter and then "divided up into a network of rivers which burnt their way through the forests and leaped precipices in a succession of cataracts and rapids". In 1859 the lava stream began to run on January 23, reached the sea, 33 miles away, in 8 days, and continued to flow into it for 10 months. On the southeast flank of Mauna Loa and 4000 feet above sea level, very easily accessible, is Kilauea, probably the most remarkable continuously active crater known. This crater, now included in the Hawaiian National Park, is sometimes called the lower crater of Mauna Loa, but it appears to be quite independent of the great mountain in its action. Kilauea, about 9 miles in circumference, is a black, slightly undulating plain of congealed ropy lava inclosed by a cylindrical basaltic wall varying from 200 to 700 feet in height.

Within the plain is a deep, fiery pit called Halemaumau whose surface of varying area melts and solidifies, rises and falls. This pit is sometimes filled with heaving lava, boiling from the escape of gases, and sometimes empty to a depth of 1000 feet. Frequently when the pit mass is thoroughly melted, red- and white-hot lava jets 10 to 50 feet high are thrown from its surface. Kilauea's first recorded eruption was in 1789 and consisted chiefly of cinders and sand. But in 1840 it discharged a flood of lava from one to three miles wide and from 12 to 200 feet deep. It flowed 30 miles in four days and leaped as a cataract a mile wide into the sea. For three weeks this "Mississippi of molten material" rushed through deep valleys into the sea, which boiled and steamed where the river of fire entered it. For twenty miles along the coast the waters were hot and the lurid glow of the flowing lava could be detected at night by ships 100 miles away. So we rightly say that Mauna Loa with its double crown of Mokuaweoweo and Kilauea surely deserves the title of "King of Volcanoes".

The earth is by no means so solid and so stolid as it seems. Its crust may be cold, but its heart is prodigiously hot. From the time when its molten waves surged beneath the sun it has never been quite *terra firma*. Tremendous, massive changes in the contours of its land and water have continually occurred. Mountains have sunk and risen, seas have waxed and waned, whole continents have appeared and disappeared. Even now the Andes and Scandinavia and Scotland and most of the coral islands seem to be slowly rising, and other parts of the world seem to be slowly subsiding.

Photo from Wide World Photos

THE 1923 EARTHQUAKE IN JAPAN

This scene of devastation marks the site of the Fuji Cotton Spinning Mills at Koyama, south of Tokio, where hundreds of operatives were trapped under the mass of brick and iron of the falling walls and roof.

But apart from these great, slow, massive see-saw movements, the crust of the earth is subject to more or less sudden vibrations, quiverings, quakings. Constantly the earth is jarred, and jolted, and tugged; twice a day not only its

waters but its continents and mighty cities are lifted and let fall by the moon; and no doubt the crust responds to changes of atmospheric pressure, and to the pounding of the tides. The more noticeable wave motions in the earth's crust are termed earthquakes, and we might expect some of these as a result of violent volcanic eruption. Such, in fact, is the case, but these movements are slight and much restricted in area. Still it is popularly

BUSINESS CENTER, TOKYO

believed that volcanic eruptions and great earthquakes are directly connected. This supposed connection was first disproved in Japan by the work of Milne, the English pioneer seismologist. Omori, the greatest authority in this matter, recently deceased, remarked that "a volcanic district may be assumed to be free from the visitation of a great destructive earthquake whose area is extensive and whose intensity is sufficient to destroy properly constructed wood or iron buildings." The subject of earthquakes is elaborately treated in another section, but we may, without repetition, note briefly some of the great quakes of modern times. In 1887 there was a very violent shock in northern Mexico, extending through most of New Mexico and Arizona, and in 1899 southern Alaska was badly shaken, but as both of these districts were thinly settled the loss of life and damage were very slight. In 1906 central California suffered, and especially San Francisco, when 1000 lives were lost and much property was destroyed by fire following the shock. In 1907 Kingston, Jamaica, was partially wrecked, and there were many changes in its coast line and harbor. In 1908, Messina and Reggio, two cities on the narrow strait that separates Sicily from the mainland, were completely destroyed with 100,000 direct victims of the earthquake. The most extensive quake

THE AFTERMATH AT YOKOHAMA

Photos from Wide World Photos

THOUSANDS BURNT AT HONJYO, TOKYO

ever reported was that of Assam, India, in 1897, destructive over 150,000 square miles and distinctly felt over an area of 1,750,000 square miles. In intensity, however, and in vital and financial loss the Japanese quake of September 1, 1923, exceeds all the others. The first reports from the scene of disaster were much exaggerated, but official figures given two months later show the magnitude of the catastrophe. The total area affected by the quake, the subsequent sea wave and fire was about 9000 square miles. The population in this area was nearly 8,500,000; and of these 200,000 were killed, 250,000 reported missing and injured and 2,000,000 rendered homeless, mainly in Tokyo and Yokohama. Scarcely any undersea changes have been detected in Tokyo Bay and very little surface change in the shaken area.

ASTRONOMERS VI

MARIA MITCHELL — AMERICA'S FIRST DISTINGUISHED SCIENTIFIC WOMAN
SIMON NEWCOMB — ILLUSTRIOUS ASTRONOMER, AND MATHEMATICIAN
BENJAMIN PEIRCE — MATHEMATICIAN AND ASTRONOMER
GIUSEPPE PIAZZI — DISCOVERER OF THE FIRST ASTEROID
EDWARD CHARLES PICKERING — MEASURER OF THE BRIGHTNESS OF THE STARS
WILLIAM HENRY PICKERING — DISCOVERER OF TWO OF SATURN'S SATELLITES
RICHARD ANTHONY PROCTOR — POPULAR INTERPRETER OF ASTRONOMY
PTOLEMY — WHO RULED ASTRONOMY FOR FOURTEEN CENTURIES

MARIA MITCHELL
America's First Distinguished Scientific Woman

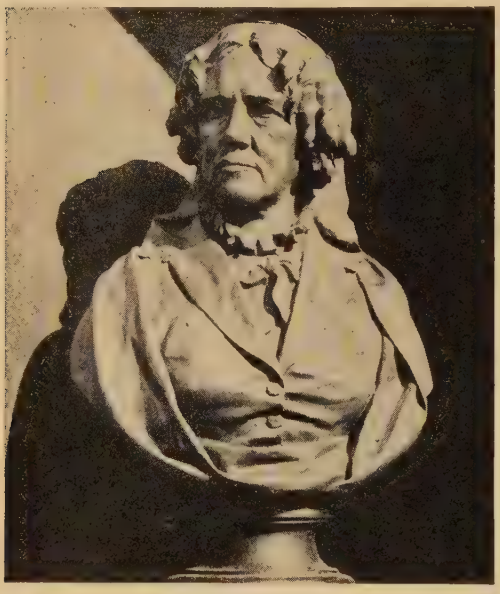
MARIA MITCHELL, who was America's first distinguished scientific woman, was born on the Island of Nantucket, Massachusetts, on August 1, 1818, of Quaker ancestry. She belonged to a large family of children and her home was plain and simple, but it had a fine intellectual atmosphere. Her father, though a business man, had a strong taste for scientific studies, particularly for astronomy, and made continuous observations with sextant and telescope. Nantucket at that time was the center of a large whaling industry, and ships' chronometers were brought to him for rating. In making the necessary observations for this, Mr. Mitchell, was frequently assisted by his children, who counted the time for him. Maria, who was the third child, showed unusual talent for such work and became her father's constant helper, developing eventually a deep interest in the subject on her own account. Her talent for mathematics was cultivated by her teachers, and by the time she left school at sixteen, she had made great progress in it, besides acquiring considerable skill in computing.

After teaching for a year or two, Miss Mitchell became the librarian of the Nantucket Atheneum, a post which she held for nearly twenty years. The hours were short and the visitors few, and she had abundant time to read and study. Here she carried on her mathematical studies and read abstruse astronomical works. A small observatory was erected on the roof of the building in which the Mitchells lived and Maria spent many evenings in it with the telescope "sweeping the heavens" for comets or other interesting objects. This practice led to the discovery of a comet in 1847 which made her famous. A few years previously the king of Denmark had offered a gold medal as a prize for the discovery of a telescopic comet. Since Maria was the first to see this one and announced it immediately to the public, the medal came to her.

Miss Mitchell received much honor for her work, and was elected to several scientific societies. In 1849 she became one of the regular computers for the American "Nautical Almanac," continuing in this position for many years. She kept up her observations on comets, took up the study of double stars and their colors, and began a study of the surface markings of the planets, Jupiter and Saturn, which she followed during the rest of her active life. Articles by her on astronomical subjects were published in *Silliman's Journal* and other scientific periodicals.

In 1857–58 Miss Mitchell made a prolonged visit to Europe, meeting many distinguished scientific men, to whom she was already known by reputation and from whom she received a most cordial welcome. After her return she was presented with a telescope from the women of America.

In 1865 when Vassar College was founded, Mr. Vassar invited Miss Mitchell to become the first professor of astronomy and the director of the observatory, which was well equipped with instruments, including an excellent twelve-inch telescope. Deeply interested in the higher education of women, Professor Mitchell devoted her energy to developing a high standard of intellectual work in the new college. She made her own courses in astronomy strictly mathematical in character and taught her students the use of the instruments, continuing meantime her own observations of comets, planetary surfaces, and double



MARIA MITCHELL

stars. She also kept the time for the college. Twice she made long journeys to observe total eclipses of the sun, both times taking groups of Vassar students with her. Many honorary degrees were conferred upon her, the last being an LL.D. from Columbia University in 1887. She died June 28, 1889.

As a memorial to her, the graduates of Vassar established the Maria Mitchell Professorship of Astronomy. On the island of her birth, a Nantucket Maria Mitchell Association has been formed by her friends and visitors to the island which is now a popular summer resort. The house in which she was born has been turned into a museum, the telescope presented to her by the women of America has been housed in a small observatory, and a director is maintained who spends part of her time on the island and part at the Harvard Observatory.

A fine bust of her was modeled in 1877 by the sister of one of her students, the expense being borne by the senior astronomy class of that year who earned the money by computing the ephemeris of Venus. It was afterwards cast in bronze and stands in a niche in front of the observatory at Vassar. A replica is in the Hall of Fame of New York University.

SIMON NEWCOMB

Illustrious Astronomer and Mathematician

SIMON NEWCOMB, the foremost American astronomer of his time and one of the most eminent men of science our country has ever developed, was born in Wallace, Nova Scotia, March 12, 1835, of humble parents. His father was a country school teacher and from him the boy obtained his early education. Apprenticed to a physician at 16 years of age, he ran away from a thankless and profitless job of general factotum and, in 1853, came to the United Sates. Here he taught school in Maryland in different country towns, finally getting one near Washington where "the Smithsonian Institution library was one of the greatest attractions". There he saw for the first time Laplace's "*Mécanique céleste*", "the greatest treasure that my imagination had ever pictured". He had in his early school days shown fondness for the study of geography and navigation and he now made application for a post in the Coast Survey. In 1857 he found employment as computer at the office of the "Nautical Almanac" — then in Cambridge, in order to be near the technical experts, especially Benjamin Peirce, of Harvard — and at the same time took the course at the Lawrence Scientific School, where he was graduated in 1858 and afterwards remained for three years as a resident graduate. He was then appointed professor of mathematics in the U. S. Navy and was assigned to work in the ill-equipped naval observatory.

Here, as better instruments were installed and he was more and more given a free hand by his superiors, he began the work of determining the error in the right ascension of stars which he believed had crept into the modern observations made at Greenwich, Paris and Washington. This task took him a number of years and in 1869 he found after working up his observations that the error he had suspected was real. This faculty of tireless patience in sifting mathematical details, combined with skill and originality in approaching difficult astronomical problems and a talent for observation, was characteristic of Newcomb.

In 1877, being then senior professor of mathematics in the Navy with rank of captain, he was assigned to the charge of the "Nautical Almanac" office which had been moved to Washington in 1866. He says: "The change was one of the happiest of my life. I was now in a position of recognized responsibility, where my recommendations met with respect due to that responsibility, where I could make plans with the assurance of being able to carry them out, and where the countless annoyances of being looked upon as an important factor in work where there was no chance of my being such would no longer exist. Practically I had complete control of the work of the office, and was thus, metaphorically speaking, able to work with untied hands."

He had soon reformed the office, which he concentrated on one floor of a modern city building, making economies that "went on increasing year by year and every dollar that was saved went into the work of making the tables necessary for the future use of the *Ephemeris*". His program included a consideration and recalculation of all the observations of all the leading observatories made since 1750 on the positions of the sun, moon and planets, as well as on the bright fixed stars, and included as well the compilation of the formulæ for the perturbation of the planets by each other. These were tasks the magnitude of which beggars a layman's understanding. "The number of meridian observations on the sun, Mercury, Venus and Mars alone numbered 62,030, and they were contributed by the observatories at Greenwich, Paris, Königsburg, Pulkowa, Cape of Good Hope and elsewhere." It was this task of "bringing the great problem of the solar system well-nigh to completeness of solution" that constituted Newcomb's life work and on which his reputation rests. It necessitated "an almost complete reconstruction of the theories of the motions of the bodies of the solar system" and "at its foundation the complete revision of the so-called constants of astronomy".

His early observations at the Naval

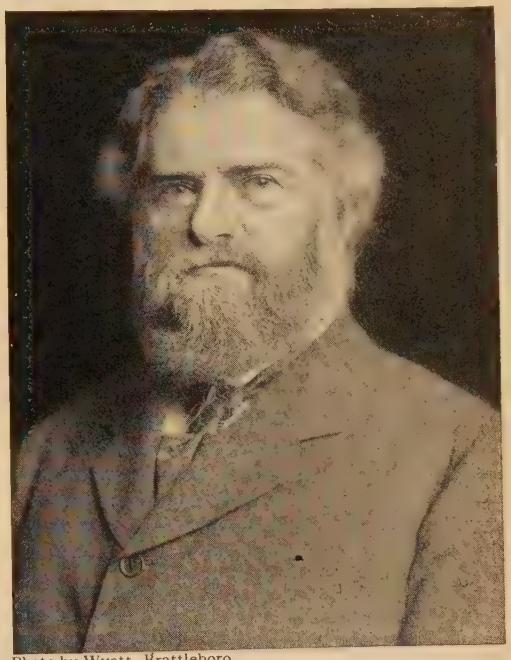


Photo by Wyatt, Brattleboro

SIMON NEWCOMB

Observatory had shown him "that the moon seemed to be falling a little behind her predicted motion". Investigation convinced him that the error had crept into the records prior to 1750 and he found evidence at Pulkowa that it was before 1675. This error, in the time that had since elapsed, had with slight additions amounted to enough to considerably affect all astronomical records. It took him years to compile the necessary data and it was only in 1878 that he published his "Reductions and Discussion of the Moon before 1750", and only on his death bed that he completed "The Motion of the Moon".

These are but a few of the herculean tasks undertaken by this marvelous worker and carried to a successful conclusion. One should consult his modest "Reminiscences of an Astronomer" to see how full he made each day of his happy life. He supervised the construction of the great 26-inch telescope for Washington, "the success of which excited such interest the world over as to give new impetus to the construction of such instruments," resulting in the still larger lenses at Pulkowa, Lick and Yerkes observatories, concerning all of which he was much consulted.

In 1884 Newcomb was invited to become professor of mathematics and astronomy at Johns Hopkins University, but he never resided in Baltimore. He resigned in 1893, returned to the chair in 1898 and was made professor emeritus in 1900. He was retired for age from the "Nautical Almanac" office in 1897. He was for many years editor of the *American Journal of Mathematics* and made more than 300 important scientific contributions to astronomy, most of them published in the "Astronomical Papers of the *American Ephemeris*". He wrote a number of popular works on astronomy and mathematics — his "Popular Astronomy" (1878) has been translated into half a dozen languages — and one or two more abstruse, besides a novel, several financial and economics works, an autobiography and articles in many magazines and encyclopedias. His versatility was almost as great as his application in his favorite field.

Simon Newcomb's work received the recognition of honorary degrees from sixteen universities, honorary membership in the great academies of science and fellowship in all the learned societies, decorations and medals galore. He was the first American since Franklin to become an associate of the French Institute. The French government made him an officer of the Legion of Honor in 1896 and a commander in 1907.

Simon Newcomb died on July 11, 1909 and was given a military funeral, having been accorded the rank of rear admiral by Congress in 1906.

BENJAMIN PEIRCE

Mathematician and Astronomer

OLIVER WENDELL HOLMES' memorial poem on one of the greatest of the American mathematicians begins:

> To him the wandering stars revealed
> The secrets in their cradle sealed;
> The far-off, frozen sphere that swings
> Through ether, zoned with lucid rings;
>
> The orb that rolls in dim eclipse.
> Wide wheeling round its long ellipse –
> His name Urania writes with these,
> And stamps it on her Pleiades. [1]

An important influence in Benjamin Peirce's boyhood was that of Nathaniel Bowditch. The story of their early acquaintance is an amusing one. Bowditch's son Ingersoll showed his schoolmate Peirce a solution of a problem that the boys had been set to work out. After some consideration, young Benjamin pointed out an error real or conceived — and Ingersoll reported the matter to his father. "Show me the boy who corrects my mathematics," said Bowditch, and the acquaintance so begun quickly ripened into the relationship of master and follower. While in college, Peirce was in Bowditch's class and regularly read the proofs of his "*Mécanique céleste*". Thirty years later, he dedicated his own masterpiece, the treatise on "Analytic Mechanics", "To the cherished and revered memory of my Master in Science, Nathaniel Bowditch, the father of American Geometry".

The outward happenings of Peirce's life are soon told: born in Salem, Massachusetts, on April 4, 1809, he was graduated from Harvard in 1829 and then taught for two years in Northampton. In 1831 he returned to Harvard and remained there, first as tutor and later as professor, until his death in 1880, the longest association, save one, of any individual with that university.

The story of his achievements, both as astronomer and mathematician, is not so quickly told. During his student days in Cambridge, Bowditch had predicted "that young Peirce would become one of the leading mathematicians of this century".

[1] Reprinted by permission of Houghton, Mifflin & Co.

At his death it was said of him that his merits ranked with the achievements of Bernouilli, Euler and Laplace. During the early days of his professorship he published a number of mathematical text-books covering the course then taught at the college, a "Treatise on Sound" on "Plane and Solid Geometry", "Treatise on Algebra", and a treatise on "Plane and Spherical Trigonometry", all of which greatly improved the then recognized methods of teaching mathematics. Their style was condensed and clear and substituted for the minute demonstrations of Euclid, the short, terse forms of geometry.

Bowditch died in 1838, and his cloak fell upon the younger man, who stood chief among the few who then had access to foreign journals. When the Harvard Observatory was founded a few years later on the occasion of the great comet of 1843, Peirce's share in the establishment was considerable. In 1841 he began a work on "Curves, Functions, and Forces" and in place of the third volume published his "Analytic Mechanics", which set forth the general principles and methods of the science as a branch of mathematical theory, and embodied in a systematic treatise the latest and best methods and forms of conceptions of the greatest geometers. This is perhaps the most characteristic of all his works, but its extreme brevity of expression makes it difficult reading for any but the initiate.

He was requested to take charge of the mathematical part of the "American Almanac", and prepared ten volumes of it, in one of them publishing a list of the known orbits of comets to which he added several approximate orbits, computed by him, of great comets which had been only imperfectly observed. For it, too, he prepared his "Tables of the Moon" which were used for many years.

After the discovery of Neptune in 1846, Peirce took the greatest interest in the researches of Leverrier and Adams, presenting to the Academy papers on such questions as: What is the orbit of the new planet? What is its mass? How much do they differ from the assigned orbits and masses?

Perhaps his greatest contribution to astronomy were his discoveries regarding the rings of Saturn. He demonstrated that the rings, if solid, could not be sustained by the planet, that satellites could not sustain a solid ring, but that sufficiently large and numerous satellites could sustain a fluid ring, and that the actual satellites of Saturn were sufficient for that purpose.

Professor Bache was superintendent of the Coast Survey, and in 1852 he induced Peirce to undertake the longitude determinations. In 1867 when Bache died, Peirce himself succeeded to the superintendency and for seven years did very active work for the organization, making tours of inspection, and raising the standard of service by giving great freedom of action to individual officers. He extended the scope of the Survey so as to carry geodetic work into interior states; as superintendent, took personal charge of the American expedition to Sicily to observe the eclipse of the sun in December, 1870; and in 1874 sent out parties to Nagasaki and to Chatham Island to take part in observations of the transit of Venus.

Between 1864 and 1870 Peirce read before the National Academy of Sciences various papers, that were later published in his "Linear Associative Algebra"; which he called the "pleasantest mathematical effort of my life. In no others have I seemed to myself to have received so full a reward for my mental labor in the novelty and breadth of my results."

During the last years of his life he published a series of eight propositions in cosmical physics, and delivered before the Lowell Institute a course of lectures on "Ideality in Science" which have been published in book form, and afford an interesting view of the speculative operations of his mind.

GIUSEPPE PIAZZI

Discoverer of the First Asteroid

GIUSEPPE PIAZZI, the famous Italian astronomer, was born on July 16, 1746, at Ponte. A youth of profound and varied learning, he was professed as a religious monk in the Theatine order, and became

well known at first as a teacher of philosophy and theology, but in 1780, at the age of thirty-four, was appointed professor of mathematics in the University of Palermo. From mathematics he passed more and more to astronomical studies, and traveled in order to acquire practical experience of the methods which obtained in contemporary observatories. Under the patronage of Prince Caramanico, viceroy of Sicily, he set up in 1791 an observatory, which was built upon one of the towers of the viceroy's palace. The position proved extremely advantageous for telescopic observations. Piazzi's earliest labors were directed to the compilation of a catalogue of stars, with their positions defined with the most sedulous precision. Such a work was greatly needed. The already existing catalogues of stars included a large number of celestial objects, but the positions which were given for them were only approximately correct; and a great deal of calculation was still necessary in order to allow for refraction, precession, and other qualifying factors. Piazzi completed two catalogues, published in 1803 and 1814. These included about 7000 stars, and were a great advance on anything previously attained, though they were destined to be superseded by Bessel's "*Fundamenta Astronomiæ*", and other later works of the same nature.

While engaged upon his first catalogue, Piazzi came upon a moving body which he interpreted as an unusually definite comet without tail or coma, but which presently turned out to be a new planet, and was, in fact, the first of the many asteroids which have since been discovered. Piazzi detected this body on January 1, 1801, but after watching it for some time he fell ill, and it was lost; and it was only rediscovered a year later by means of the calculations of the mathematician Gauss. Piazzi named this first-known asteroid "Ceres," in honor of the ancient goddess of Sicily.

Piazzi accomplished a great variety of most valuable work at Palermo. Thus, he was the first to notice, in 1792, the large proper motion of 61 Cygni, and to point out that this probably indicated comparative nearness to our solar system. Again, he expended a vast amount of labor in searching for stellar parallaxes, and claimed to have discovered these apparent movements, of very considerable size, in the case of Sirius, Procyon, Vega and Aldebaran; but it has since been shown that his results were actually due to the imperfections of his appliances. Nevertheless, in the great vertical circle made for him by Ramsden in 1789, he possessed the finest instrument of the time for determining celestial positions. Piazzi died at Naples where, in 1817, he had been appointed director of the government observatory, on July 22, 1826.

EDWARD CHARLES PICKERING

Measurer of the Brightness of the Stars

EDWARD CHARLES PICKERING, one of the greatest American astronomers, was born in Boston, on July 19, 1846. He was interested in science from his earliest years, and as a boy constructed a telescope, tailless kite, camera obscura and an electrical machine. He also devised a perpetual calendar and a planisphere, and was an expert amateur photographer in the days when there were not even many professionals.

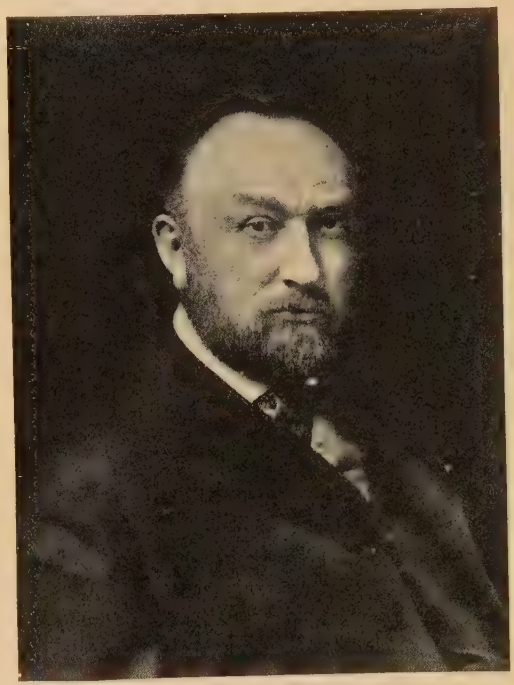
His school education was, until his sixteenth year, almost entirely classical, but in 1862 he entered the Lawrence Scientific School of Harvard University, studying especially mathematics, chemistry, physiology and mineralogy, and graduating with high honors. He was at once offered a position in the school as teacher of mathematics; in 1867 he was given a better appointment in the Massachusetts Institute of Technology, and was soon after made Thayer professor of physics, a chair which he retained until 1876. He here organized and developed the first physical laboratory for general instruction in the United States, and prepared a text-book, entitled "Physical Manipulation", which remained for forty years the chief manual on the subject. Among his practical inventions was a telephone receiver having a flexible diaphragm, constructed in 1870; this was exhibited before the American Association, and proved an effective instrument for speech

at a distance. In 1876 he was appointed professor of astronomy and director of the observatory at Harvard, a position which he held with increasing reputation until his death on February 3, 1919.

Professor Pickering's first, and in some respects the most notable, work was in stellar photometry. For this purpose he devised the "meridian photometer," an instrument so constructed as to show at the same time a direct image of the star to be measured, and the reflected image of the Pole Star, which he took as a standard, second-magnitude star. One of these images having been modified by polarization until the images of the two stars appear of precisely equal brilliancy, and the degree to which the former had been modified having been read off on a scale, the observer can see at a glance the difference of magnitude, and thus a precise measure of brilliancy is obtained. Many thousands of stars were measured with this instrument. Professor Pickering then made another and larger photometer on the same principle, and with it measured the brilliancy of many more stars. Further, one of these instruments was sent out to the southern hemisphere, and similar measures were made of the southern stars.

In 1886 increased means permitted a great extension of the work of the observatory. A station was established in Arequipa, Peru, and was equipped with instruments like those in Cambridge. Since then the principal researches undertaken at Harvard have been made to include all portions of the sky, from the North Pole to the South Pole. They have yielded many important discoveries, not only of new stars and of large numbers of variable stars, but also of a wholly new class of double stars, whose binary character is only revealed by peculiarities in their spectra. In 1890, under his direction, the first volume of a catalogue of stellar spectra was published, a work which he had undertaken as a memorial to Dr. Henry Draper. It includes investigations of the spectra of 10,351 stars, covering the northern hemisphere and part of the southern. Before his death, the first of a new series of volumes of spectra was published; the entire Draper catalogue contains the class of spectrum of 200,000 stars, and when completely published will fill nine volumes. Ample material is thus provided for researches into the nature and distribution of stars; and Professor Pickering himself at once proceeded to examine the records of the earlier volumes in order to ascertain the distribution of the stars of the various types. He found that while most classes are fairly equally distributed, stars of the first type cluster near the Milky Way.

With regard to the evolutionary history



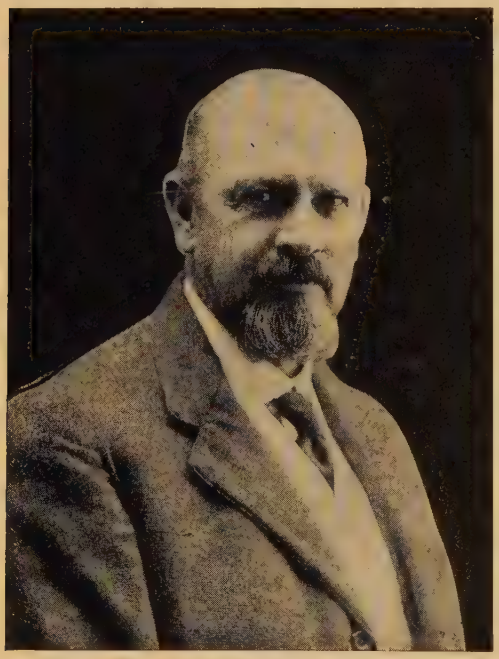
PROFESSOR E. C. PICKERING

of the stars, a problem to which he gave much attention, Professor Pickering agreed with Vogel. "In general," he concludes, "it may be stated that, with few exceptions, all the stars may be arranged in a sequence, beginning with planetary nebulæ, passing through the bright-line stars to the Orion stars, thence to the first-type stars, and by insensible changes to the second- and third-type stars. The evidence that the same plan governs the constitution of all parts of the universe is thus conclusive."

In 1880 Professor Pickering made a most important discovery — namely, that of the

first spectroscopic binary, Zeta Ursæ Majoris. It was confirmed shortly by Vogel's similar discovery at Potsdam, and a most fruitful branch of research was thus opened up to astronomy.

Meanwhile, Professor Pickering was also carrying out a very ambitious scheme in astronomical photography, on a larger scale and on a different plan from any in use elsewhere. More than two hundred thousand overlapping photographs have been obtained, covering the entire sky many times; and this unique collection furnishes the only available record of the



WILLIAM HENRY PICKERING

principal events in the stellar universe occurring during the last quarter of a century. By means of this great sky-chart many new and temporary stars have been discovered, including the new stars of 1887 in Perseus, of 1893 in Norma, of 1895 in Argo, of 1895 in Centaurus, of 1898 in Sagittarius, and of 1900 in Aquila.

Professor Pickering also gave much attention to variable stars, especially to short-period variables of the Algol type; and he was one of the first to suggest the eclipsing-satellite theory of the latter, a conjecture which has now been fully established by spectroscopic investigations. He also made photometric observations of the planets, asteroids and satellites, and by this means determined the sizes of many of the asteroids, and of the satellites of Mars.

Among the honors conferred on Professor Pickering was membership in the Royal Society of London, the French Academy of Sciences, the Royal Prussian Society, the Imperial Academy of St. Petersburg, and the *Academia dei Lincei;* he received many honorary degrees and medals from learned societies, and was one of the few Americans who received the Prussian *Ordre pour le mérite.* He unquestionably made an indelible mark in the history of astronomy.

WILLIAM HENRY PICKERING
Discoverer of Saturn's Ninth and Tenth Satellites

WILLIAM HENRY PICKERING, the brother of the preceding, was born in Boston, February 15, 1858, and was an instructor at the Massachusetts Institute of Technology, where he had been graduated in 1879, and assistant professor at Harvard observatory. He was head of the expeditions sent out to observe the total solar eclipses in Colorado (1878), West Indies (1886), California (1889), Chile (1893), Georgia (1900), and he visited Hawaii in 1905 and the Azores in 1907 in order to compare their crater formations with those of the moon. It was he who established the Arequipa (Peru) observatory for Harvard, and erected the observatory and telescope for Percival Lowell at Flagstaff, Arizona. He lives on the island of Jamaica, where he established another of Harvard's observatories in 1911. His discoveries include the ninth and tenth satellites of Saturn, and he explained why the former revolves in a direction opposite to the others.

Mr. Pickering began publishing papers in 1888 in *Popular Astronomy* and other astronomical periodicals, and his contributions to the science already number over three hundred. His books include "Guide to Mt. Washington Range" (1882), "The Moon" (1903) and "Mars" (1921). He received the Lalande prize in 1905 and the Janssen medal in 1909.

RICHARD ANTHONY PROCTOR
Popular Interpreter of Astronomy

RICHARD ANTHONY PROCTOR was born in London on March 23, 1837. He was educated at King's College, London, and St. John's College, Cambridge, and, on leaving the university, read for the bar, but soon gave his attention to science. His first essay in astronomical writing, an article on double stars, appeared in the *Cornhill Magazine* in 1865. This was followed by a short but notable work on "Saturn and his System", which brought his name to the notice of the scientific world, and in 1868 his "Half-Hours with a Telescope", written for publishers who paid him twenty-five pounds for it, was the first of his works to acquire that wide popularity which many of his later writings enjoyed. Before he died he had seen twenty editions of this book.

It was not until 1873 that Proctor began lecturing on astronomy. He visited the United States and Australia, and in both countries achieved immediate and enormous success on the lecture platform. In speech, as in writing, his wonderful power of lucid exposition made his work extraordinarily effective in popularizing astronomy, and in correcting prevalent errors by showing their unscientific basis.

Proctor's second wife was from St. Joseph, Missouri, and he went there to live until, in 1887, the family moved to Orange Lake, Florida. He died in New York on September 12, 1888, while on his way to England with which he had all this time retained an intimate connection. He wrote papers for the *Monthly Notices* of the Royal Astronomical Society, and in 1881 founded the popular scientific magazine *Knowledge*, published in London. During his lifetime he published as many as fifty-seven volumes, and at his death left one unfinished, "The New and Old Astronomy", edited and completed by A. C. Ranyard and published in 1892. Among the more popular of his books are "Other Worlds than Ours", "Half Hours with the Telescope", "Elementary Astronomy", "The Orbs Around Us", "Our Place Among Infinities", "The Sun", and "Transits of Venus".

Proctor was not, however, by any means a mere exponent of results which had already been arrived at, although perhaps his most important services to science lay in that direction. He pursued researches on his own account, and some of these have been of considerable value. His investigations into the rotation period of the planet Mars resulted in a determination which has been said to be of a precision unapproached in the case of any other heavenly body except that of the earth itself. The period was worked out by Proctor to minute fractions of a second.

His researches into the constitution of the Milky Way elucidated the independent nature of this structure. It is to Proctor, as the late Miss Agnes Clerke remarks, that we owe the discovery that "the stars forming the galactic stream are not only situated more closely together, but are also really, as well as apparently, of smaller dimensions than the lucid orbs studding our skies.

"By the laborious process of isographically charting the whole of Argelander's 324,000 stars, Proctor made it clear, in 1871, that the brighter stars show, in their distribution, a detailed relationship to the complex branchings of the Milky Way, avoiding, to a marked extent, its vacuities, and thronging its denser convolutions. It follows that they must be actually intermingled with them. So that, for every triton sun, there are doubtless swarms of minnows."

Another amazing phenomenon, brought to light by Proctor's indefatigable charting — this time by the charting of stellar proper motions — was what he himself called "star-drift". Large groups of stars, often at great distances apart, and with no other apparent connection, were found to progress together at the same rate and in the same direction across the sky. The reality of this common drift has been proved by the spectroscope. The immensity of the system revealed by this common star-drift is quite unthinkable, the stars being, in most cases, almost infinitely remote, and consequently at enormous distances from one another, yet they are found to be united by some mysterious tie.

These important discoveries show how far Proctor's astronomical work was from being merely popular or expository. They prove him to have been a profound as well as an exceptionally lucid thinker, and to have penetrated far into the secrets of the celestial system which he did so much to elucidate for others.

PTOLEMY

Who Ruled Astronomy for Fourteen Centuries

CLAUDIUS PTOLEMÆUS, the great expounder and perfecter of the older geocentric system of astronomy, lived in the second century of our era. Almost nothing is known of his life, except that he was a native of Alexandria, and that he made observations as early as 127 A.D. and as late as the year 150.

Besides being the greatest astronomer of his day, Ptolemy became illustrious for his work in pure mathematics, which marks the beginning of the study of trigonometry, and still remains the foundation of that science. He was also an eminent geographer, and in this subject, as well as in his astronomical teaching, was known to Roger Bacon, who carried forward his geographical theories after eleven centuries.

It was by his astronomical system, however, that Ptolemy rendered his greatest service to science, and it is with the treatise relating to this system that his name will be immemorially connected. The modern progress of knowledge, which has gained so much by the refutation of the system expounded in the "Almagest", has embodied the record of this work in the history of its forward march. In the "Almagest", or "Syntaxis", Ptolemy reviews the theory of astronomy as far as it had been carried by Hipparchus, whose theories he improved and corrected in many directions, notably with regard to the lunar theory and the planets. The theory of the sun, on the other hand, he left as Hipparchus had formulated it; and the consequence is that his tables gave very erroneous values, inasmuch as the theory of Hipparchus had made the mean motion of the sun too small, and the error in the course of the intervening three centuries had grown to be very considerable.

Ptolemy adopted the system of epicycles and eccentrics used by his predecessors, using it, indeed, as a mere geometrical device to explain the observed motions, and not professing to give thereby a representation of the actual system of the universe. He accepted as a working basis the views generally held at the time with regard to the construction of the world, and endeavored to bring together into one complete and adequate theory all that was known of astronomical science.

Thus, Ptolemy's ground-plan consisted of a heavenly sphere carrying the fixed stars and turning upon a fixed axis, with the earth, an infinitesimally small body in comparison with the heavens, as its center.

Ptolemy denied any motion, either of rotation or translation, to the earth, maintaining that, if there were any such motion, it would be in proportion to the earth's great mass, and that consequently animals and other objects would be thrown outwards by centrifugal force, and would be left behind in space! The arrangement of the planets, from the earth outwards, was in the following order: Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn. The sun and moon were usually regarded as of the number of the seven planets, but Ptolemy does, in fact, in considering the motions of the planets, refer to them as "the five wandering stars", and distinguishes them from the sun and moon.

Hipparchus had left his theory of the moon incompletely developed, confessing that there remained certain inequalities for which his calculations failed to account, but leaving the nature and explanation of these inequalities to future investigation to solve.

Nothing was really added to his ancient work, however, until Ptolemy attacked the problem, and at last succeeded, by means of a combinaton of epicycle and eccentric, in formulating a theory which allowed of the determination of the moon's apparent place with an accuracy as close as was practically necessary in his time, when instrumental efficiency did not make it possible to ascertain the positions of heavenly bodies within a possible error of 10′.

With the same care and mathematical ingenuity, Ptolemy corrected the theory of each of the planets. The motions of these bodies presented great difficulties, which is not surprising when we consider that the complicated observed motions had to be explained in the light of an earth-centered universe, and by means of combinations of circular motions. Yet Ptolemy achieved considerable success in this task. As John Dreyer says: "That the system as a whole deserves our admiration as a ready means of constructing tables of the movements of sun, moon and planets cannot be denied. Nearly in every detail (except the variations of distance of the moon) it represented geometrically these movements almost as closely as the simple instruments then in use enabled observers to follow them, and it is a lasting monument to the great mathematical minds by whom it was gradually developed. It appears from many statements, not only of Ptolemy himself, but also of his commentators, that they merely considered the numerous circles as a convenient means of calculating the positions of the planets."

Ptolemy was acquainted with the phenomenon of precession, discovered by Hipparchus, and corrected the value found for it by the latter to the roughly approximate and convenient figure of 36″ a year, or one degree in a hundred years. But it was not until centuries later that the true value of Ptolemy's work came to be appreciated. In the intervening centuries — that is, after a short period of fame and commentaries — many of the treasures of pagan thought were forgotten.

Until the seventh century, the achievements which had been made in astronomical science by the ancients may be said to have been practically non-existent for Christian Europe. The earth was again regarded as flat, with the heavens spread tent-like over it, while the setting sun passed behind a northern barrier or wall. The "waters above the firmament" were a feature of early medieval cosmology, and constantly appear as an important agent in qualifying the heat of sun, moon and stars, or even as a provision for the future final extinction of these fiery bodies. Occasionally a more enlightened teacher, such as St. Isidore of Seville in the sixth century, would venture to put forward tentatively, as "a doctrine which has been taught", the theory of a spherical earth, or of a spherical revolving heaven. By the next century these opinions had considerably gained ground, and are boldly stated by the Venerable Bede in his treatise "Of the Nature of Things". Bede returns to the spherical earth, the seven planets (including, of course, the sun and moon) revolving about it, and to the fact of the sun being much larger than the earth; he adheres, however, to the inevitable waters above the firmament, in spite of having asserted the sphericity of the heavens.

From this time onward we find a gradually increasing acquaintance with the works of the Greeks, and at last, in the thirteenth century, a clear exposition by St. Thomas Aquinas, following Ptolemy in many points, of Aristotle's book on the heavens and the earth. Roger Bacon in the same century also knew and taught the Ptolemaic theory, with great independence of thought. From this time onward, consequently, we find a growing discontent with the unduly speculative character of scientific teaching that was common in those days, and one of the earliest indications of this change of outlook was a desire for first-hand acquaintance with the writings of Ptolemy himself. The spirit of ancient Greece sent a breath of new life over the mind of Europe, and astronomy benefited as much as any science, from the fresh spirit of humanism and youthful intellectual force. The extraordinary insight shown in the work of Nicolaus de Cusa, who wrote in the first part of the fifteenth century on "learned ignorance", finds its complement in the ardor for correct knowledge which led to the earnest study of Ptolemy, and at last to the publication of his original works. The first Latin edition was published in 1515, but not from the original; a translation from this latter first appeared in Paris in 1528, while the Greek original was printed at Basle in 1538. Five years later the "*De Revolutionibus*" of Copernicus appeared, and Ptolemy's long reign was at an end.

TIME'S VOYAGE WITH LIFE'S TRIO — MEMORY, HOPE AND PLEASURE — PAST, PRESENT AND FUTURE

A SYMBOLICAL SCULPTURE BY STECCHI, ENTITLED "LA TRAVERSÉE DE LA VIE"

LIFE'S ULTIMATE DESTINY

What Will Happen to Life Should the Earth and the Universe Run Down?

THE DISCOVERY OF INHERENT ENERGIES

THE greater part of our long study of life has been concerned with its history, from which we have been enabled to infer something of its nature and mode of action. We have now to sum up the situation as it exists for life upon our planet, and to say what we can as to its probable destiny. Our inquiry must of necessity be confined to life, where alone we certainly know it, as a denizen of the astronomical body called the earth. But we shall be careful not to deny that the phenomena of life, which we have come to regard as essentially phenomena of mind, may be exhibited on other worlds than ours.

It may be, indeed, that in the natural history of the various worlds which inhabit space there is a period during which life appears, and that this period has yet to be in the case of such a planet as Jupiter, while it is already past in the case of such a small and rapidly cooled body as the moon. Since the discovery of evolution in the middle of the nineteenth century, there has long been a tendency on the part of many students to assume that life is solely a terrestrial phenomenon, which could not occur elsewhere than under the conditions of our earth. That is surely altogether too material and local a view of life, and one which is utterly incompatible with the conception of life as a manifestation of mind. Wherever not-mind is, as matter and energy, there mind must potentially be, and may find ways of expressing itself. Granting that, and no longer presuming to assume that the highest thing in the universe is confined to one tiny satellite of one of the least considerable of hundreds of millions of suns, we may proceed with the special inquiry which concerns us so intimately, and which alone we can hope to conduct with any success. What are the future prospects of terrestrial life?

Destruction of the fruits of all the ages of vital progress was Darwin's "pet horror". His great advocate and champion, Huxley, dealt with the subject in more detail.

"If our hemisphere were to cool again, the survival of the fittest might bring about, in the vegetable kingdom, a population of more and more stunted and humbler organisms, until the 'fittest' that survived might be nothing but lichens, diatoms, and such microscopic organisms as those which give red snow its color; while, if it became hotter, the pleasant valleys of the Thames and Isis might be uninhabitable by any animated beings save those that flourish in a tropical jungle. They, as the fittest, the best adapted to the changed conditions, would survive."

Of these two possibilities, destruction by cold is what we apparently have to anticipate. Yet destruction by heat is not inconceivable.

There is a Biblical verse, "The heavens being on fire, shall be dissolved, and the elements shall melt with fervent heat; the earth also and the works that are therein shall be burned up." Astronomy is able to show that such results might, indeed, follow from natural causes under certain conditions. For instance, the temperature of the crust of the earth might be greatly raised by an outburst of heat from its central core. In such a case terrestrial life, as we know it, would disappear, and man would be no exception to the rule. Some geologists of today suppose that there is

something, after all, to be said for the "catastrophic" geology which Lyell, in his "Principles of Geology", overthrew; for there are physical facts which suggest that the hot center of the globe may indeed have asserted itself in this way from time to time. But contemporary opinion is still against this view.

Then there is the possibility, by no means unreasonable, of outbursts in the sun. "Were the sun to suddenly blaze out, like the 'temporary' stars recorded in the annals of astronomy, then the earth would certainly be burned up, and at least everything on its surface would be reduced to ashes." But there is another remarkable possibility.

How long should we have notice beforehand of a stellar collision?

No bright star is to be feared as an enemy of the sun, and therefore of the earth. Even if the nearest known star were traveling towards the sun at ten miles a second, it could not reach us for scores of thousands of years. But dark stars, which astronomers cannot detect, have to be reckoned with; and it is quite possible that, in the course of the sun's journey through space, such a star might be encountered.

Should such a collision occur, there would be a rapid end of terrestrial life. We need not fear, however, that anything of the sort may be now imminent, for astronomers would be made aware of what was to happen long before the actual catastrophe occurred. When the approaching dark body came within a certain distance of the sun, it would shine by reflected light, as the planets do. It would first become visible far beyond the solar system. For a long period its motion would be very slow, owing to its great distance from the sun. It would probably be first seen as a faint star of, perhaps, the ninth magnitude.

Ellard Gore has made some calculations as to the movement of such a body, on certain reasonable assumptions — as that it had the same mass as the sun. In such a case we should have long notice of the ultimate event. But a smaller body, even only the size of the earth, would give us less notice, though its advent would be no less disastrous.

According to Gore, "Such a body may possibly be now approaching us. If only the size of the earth it might easily escape detection until well within the orbit of Uranus, and we might then have only a few months' warning before the final catastrophe occurred." But the long records of the past immunity of the sun and earth from such events suggest that we need have little fear. Probably unattached and irresponsible celestial bodies, liable to "run amuck" in the fashion suggested, are very few if any. Else the solar system could scarcely have been traveling through space at twelve miles a second for hundreds of millions of years without mishap.

Indeed, it is not heat but cold that we — or, rather, our remote successors — have to fear. To this Professor Percival Lowell would add thirst, on the hypothesis that the earth is gradually losing its water, as he believed is happening on Mars, and as seems to have happened in the case of the moon. We know no form of life that can exist without water, which is essential for the chemical phenomena by means of which life shows itself. But this loss of the earth's water is a doubtful question, which need not here concern us further. It is well to remember that the earth is much larger than either Mars or the moon, and therefore has much greater gravitational control over the water and other gases in its atmosphere. But, as regards the advent of cold, the case is much more definite.

The faultiness of the theory of final poison by noxious gases

In our study of the planetary facts of life nothing has become more evident than their cyclical character. All sorts of definite processes, which tend towards a limit in some direction, are compensated by other processes in the opposite direction. There used to be a theory that the amount of carbon dioxide gas in the atmosphere must accumulate until the last man, or chamois, expired of suffocation, on the top of the highest available mountain, drowned at last in the rising sea of irrespirable gas.

But speculators forget that the green plant everywhere decomposes the carbon dioxide produced in such large quantities by the respiration of animals, and restores the oxygen to the atmosphere, retaining the carbon which animals will consume at a later date, and will burn over again. This is the great carbon cycle, an essential part of the balance of living nature; and, so far as it is concerned, the earth might bear abundant life forever.

Similarly, we discover that the death of innumerable hosts of living individuals, every day, does not mean the locking up of valuable chemical elements and compounds which life requires; for other forms of life, called the microbes of putrefaction, attack these corpses, and unlock their invaluable contents, which then become available for further developments of life. Thus, every atom in the body of any one of us, or of any creature now alive, must have been part of the body of myriads of other living creatures in the past, and their death has not been allowed to arrest the fruitfulness of life.

And yet, notwithstanding these and many other instances of the extraordinary economy with which life manages its affairs, the fact remains that life does require an income to spend, and cannot do without it. That income is the light and heat of the sun — or rather, that minute proportion of the light and heat of the sun which strikes our earth and pierces our atmosphere. It is of no avail to point out how astonishingly well this income is managed. It is handed on, in many forms, from one living creature to another, especially from the green plants as a whole to the animal kingdom, and it serves the purposes of all in turn. But it is ultimately spent, in the long run.

Every moment of our lives, at this, as we now read or write, *heat* is leaving our bodies and passing into surrounding objects. That heat was originally solar energy. It traveled from the sun, reached certain green plants, was turned by them into starch and sugar, which we consumed, and then burned up in our bodies, producing the heat which is now leaving them. That heat is lost to life.

The dependence of all life on the earth upon the sun

It is not lost to the universe; it is not annihilated, but it cannot be *used* again, any more than the wheel can be turned by the water which has passed. The process which our own bodies are illustrating at this and every moment is none other than a minute part of the general loss of availability which Lord Kelvin called the "dissipation of energy", a process which persists, no matter how wisely or efficiently the energy is employed meanwhile. It is dissipated or degraded, tending to assume the unemployable form of a dead level of heat. Living creatures make amazing use of the energy which passes through them, but it undergoes dissipation through them, nevertheless, as everywhere else. In this great respect there is no cycle of life, no balance of living nature.

On the contrary, life is a beneficiary of the sun. So long as we living creatures receive a sufficient income, or indeed any income, of energy from the sun, we will use it to the best of our ability, and make it serve the life of a long succession of living forms, green plants, men and microbes, in turn, but even we cannot spend our cake and have it. Some waste, in the form of the dissipation of energy, which goes on everywhere else, must occur with the energy which passes through our bodies; so that, if life is to persist, the solar allowance for it to live upon must be maintained. Marvelous though life be it cannot create physical energy. There is no such thing as "vital force" in the sense of energy *made* by life, and added to the energy of the physical universe.

Something of the sort used to be thought formerly, but experiment has long since proved the contrary.

How long will the sun supply the wherewithal for life's energy?

Every iota of energy displayed and expended by every living creature has had to come from somewhere. Life did not make it, and cannot do without it, marvelously though life may transform, use and direct it. All these latter processes are within its

competence, but to create energy and to do without energy are not. To this rule man is no more an exception than the humblest form of life that can be named.

The duration of life's solar income is therefore a matter of the first and last importance. So long as that income is maintained, life will use it. We need not fear that life will grow old, or lose its powers. It is new every morning, like the rest of the universe, and will be gaily inventing and projecting and achieving a thousand millions of years hence as today, if only it has the wherewithal. But the astronomers and physicists are upon nothing else so definite and so decided as upon the impossibility of the sun's eternally maintaining the output of energy by which terrestrial life lives. They point out that the sun is no more capable of creating energy than life is, and that its tremendous output cannot be compensated by any influx from without.

The continuous loss by the sun of its store of energy

The available sources of such influx are the light and heat received upon the sun's surface from other stars, and the impact of meteorites and other such small bodies which the sun may sweep up on its journey through space. The total solar income from such sources is practically negligible; and the necessary conclusion is that the sun is losing its store of energy.

It may or may not be actually falling in temperature — that is a question in cosmical physics of great difficulty — but the store of energy must be diminishing, and must some day be depleted. If the sun were made of coal and were burning, it would have burned itself out long ago. If it obtains its energy from its own gravitational shrinkage, that process is obviously finite. Even if there is present a proportion of radium in the sun, as astronomers have inferred from the known presence of helium, a radium product, yet, even so, the sun cannot produce energy forever. Furthermore, space is full of dead suns, dark and cold bodies which were doubtless once bright and hot; and they evidently indicate the state of things to which the brightest suns must come.

What, then, of the prospects of terrestrial life? Whether or not the sun be now actually falling in temperature, that fall must some day occur. The sun will slowly begin to grow cold. Less heat and light will reach the earth. The polar ice-caps will increase in extent, and life other than that of the humblest sea-water forms will be made less possible than ever at the extremities of our globe. The flora and fauna of the earth will be necessarily modified in form and distribution, as the climates of the various zones slowly alter.

The shrinkage of terrestrial life in proportion to the loss of solar heat

Alpine forms of life, we should suppose, will be left to keep the flag flying in what are now the temperate zones. The animals and plants which now exist in colder latitudes, or corresponding types of the future, will replace the forms which are adapted to greater warmth. The climatic conditions to which we are accustomed will be maintained longest in the torrid zone, where the rays of the waning sun fall most directly on the surface of the earth, through the shortest distance of atmosphere, and thus retain most of the power with which they were endowed when they reached the outer limits of our globe's gaseous envelope.

We can imagine that the struggle for existence, not least within our own species, would become intensified under such conditions. The animal and human population of the globe would be very seriously diminished in numbers, for the sufficient reason that the supply of nourishment would be restricted. The green plant is what would suffer first when the supply of solar energy failed; and the serious limitations of the area on which food could be grown would determine the numbers of the animal kingdom. There can never be more mouths than there is food to feed. We must not suppose that mere improvement of devices for protection against the cold would be of any substantial use. No doubt, cosy homes of sorts could be made beneath the surface of the ground, where any temperature desired might be obtainable, perhaps long after the sun's heat had begun sensibly to fail. But mere

protection against cold is of no use if there is nothing to eat; and for food we require the coöperation of the green plant. Our successors might learn to do without that coöperation, as has been suggested elsewhere in this work, but they would still be dependent upon the solar energy even though they had contrived some other transformer than the green leaf, and that energy would be failing. Therefore, the numbers of animals (if room could be found for any), and of men, would be seriously diminished in proportion to the diminution of life's solar income.

The failure of all life with the failure of daylight

The last scene of all, or last but one, in this eventful history would presumably be the disappearance of all warm-blooded forms of life — man, birds, and mammals in general. All forms of animal life, or nearly all, would have to follow. The green plant, living in its elegant and inimitable way upon the light of day, would have to vanish when day became gray and dark; until at length, as Huxley suggested, "the 'fittest' that survived might be nothing but lichens, diatoms, and such microscopic organisms as those which give red snow its color". When light fails, all the higher forms of life must fail. Light is not merely to see by. The higher animals and men could not grope about in darkness, and make the best of it, because they would have no food to live upon, failing the light-energy which the green plant converts into our nourishment. Failing the green plant, and the bread which is its typical product, the staff of our life would be removed, and we should fall.

The humbler forms of life that will be left to the last

The history of terrestrial life would thus present a long, slow rise and a long, slow decline. The latter stages would be represented by humble forms of life not so dissimilar from those in which life began. It is probable that life began in darkness upon our planet, at a time when the rays of the sun could not pierce the dense atmosphere of those hot times. And on our present supposition life would show its declining stages in darkness also, though in darkness of a very different kind, due not to any dense screen of opaque gas, but to the feebleness of the sun's rays, now obstructed by an atmosphere of increasing rarity. We may suppose that life would hold out as long as water remained liquid. The astonishing resistance of living organisms to cold has been completely demonstrated of late, and contrasts notably with their comparative susceptibility to heat. Bacteria will survive six weeks' exposure to the temperature of liquid air. Arctic explorers have found living organisms in sea-water in all latitudes. Assuming, then, that water remained at all upon our planet at this epoch, we must suppose that life of humble sorts would persist — at any rate, as long as that water remained liquid.

Last stage of all, that ends this strange, eventful story

Finally, no liquid water remaining, and what water was left to the earth being all frozen, the last forms of life would have to come to an end. This cold graveyard of an earth could not expect to send forth new life until some celestial collision provided new sources of heat and light — in the course of which event, probably, the earth itself would be transformed and its identity lost.

Such, in all moderation and sobriety of statement, seems the probable terrestrial prospect. We may not nowadays accept the view of Lord Kelvin, that the loss of available energy is a universal process and that there can be no resurrection. Elsewhere in this work the modern arguments against that view, which was always opposed by Herbert Spencer, have been detailed. But those arguments do not at all affect our belief that the sun must cool. On the contrary, the newer astronomical evidence as to the evolution of stars, beginning with the celebrated work of Sir Norman Lockyer, strongly confirms our belief as to the cold future of the sun. Nor is there any question as to the dependence of earthly life upon the sun. There may well have been an earth-sustained period of earthly life, when the surface of the planet

was so hot that the sun's rays were not needed for the maintenance of life. That stage has passed, and our dependence upon the sun is absolute.

New discoveries in physics may greatly prolong our estimates as to the sun's powers of future radiation. The presence of radium in the sun may vastly extend the duration of its powers, but that cannot be more than merely putting off the evil day.

Can mind do anything to avert life's overthrow?

Is there, then, no imaginable escape for terrestrial life, including the human species, from the tragic and chilly fate which Darwin describes in a letter to Sir Joseph Hooker, with the comment, "*Sic transit gloria mundi*, with a vengeance"? Our answer to this question will depend upon our theory as to the nature and powers of mind. On the view which many men of science entertained in the nineteenth century, the possibility of any rescue by the mind does not arise. For we may remember that upon the materialistic or mechanistic view, the mental phenomena displayed by living creatures, of course including those displayed by man, are mere "epiphenomena", as Huxley called them, by-products and consequences of the chemistry of the organism, *and impotent to effect any changes in anything*. We think we do things, but we err; they are done to us, and we notice them. On this theory, life must go through with its sentence, and no help can be expected from that showy but impotent by-product of life which we call mind.

But in the twentieth century, under the guidance of such men as Bergson, Driesch and McDougall, we think rather differently of mind, and are disposed to credit it with rather more powers than the materialists supposed. Let us for the moment leave over the philosophical considerations, and ask what mind might do — if, indeed, mind can do anything.

It could not create energy available for life's purposes when the sun's energy failed. It could not construct those machines we call the bodies of living creatures in such a way that they would work without energy. Not for a moment can we credit mind with the power to abrogate and defy the laws of the physical universe. If what we call the law of the conservation of energy be valid, if the truth that you cannot spend what you have not got to spend remains true, then life in time to come will require *a source of available energy* for working its machines, no less than today or in the past. A muscle may be the most economical machine in the world, turning into mechanical work no less than 25 per cent of the power supplied to it; but power must be supplied to it, nevertheless. The light of the glow-worm may be as superior in efficiency to any lamp made by man, as a muscle is to any of his machines, but it requires energy for its consumption, none the less. If the sun is to fail us, where on earth is the energy which life might use to live by, supposing that mind could somehow learn how to use that energy in the place of sunlight?

The energy that is everywhere, waiting for mind to find it

Everywhere, is the answer. Within every atom exists a fund of energy so large, as compared with all the energy hitherto known, that this becomes a mere nothing. The present Lord Rayleigh, distinguished son of a distinguished father, has constructed a radium clock which will go for ages without winding. This clock does not contravene the law of the conservation of energy. It is driven by the explosion of radium atoms with which it has been supplied, and the liberation, as available energy, of the energy by which those atoms had been built up and were held together. As for heat and light, essentially identical with the heat and light whereby the sun maintains the life of our planet, we know well that radium produces heat and light in extraordinary quantities for astonishing periods, without any energy being supplied to it. They are the transformed energy which was within the radium atoms. If we had enough radium, and could get it together, or set up small "suns" of it here and there, we could live by it, and vegetables could grow by it, just as they can be grown by electric light. Only, we have

every reason to suppose that there is but comparatively little radium in the crust of the earth.

Our answer, however, to the question "where on earth" the supply of energy is to be found, was "everywhere". And it is so. Radium atoms only illustrate what is the fact of all atoms. The atoms of this ink and paper, of the air about us, of everything we touch or see, are crammed with energy. Probably they all yield this energy in the course of time, though none do so as rapidly as radium does. If we could tap the energy of the atom, we should not need to trouble ourselves about the possible exhaustion of the stored-up solar energy of coal under our feet, or even the gradual failure of the sun's powers.

Will man ever find a clue for using gravitation?

That is to say, the intra-atomic energy is so enormous in its amount, there are so many atoms to be had, and their store is so rich, that they would avail for countless ages. Readers of another section will be well aware that, even so, the store of energy available would not be infinite. No more than the living organism, or than the sun, does the atom *create* energy. But, given access to the intra-atomic energy, man's dependence upon the sun would cease, provided that he could invent the necessary machinery for turning the energy from this new source into the forms he wants — as to which proviso there need be no doubt.

Another possibility, of strange speculative interest, has been hinted at by M. Maeterlinck. The time may very well come when man's mind obtains the clue to the action of gravity, and thereafter the power to control it. Should such a time come, man might be able to steer his planet where he pleased, being no longer subject to the continuous action of the uncontrollable force which binds us in our orbit round the sun.

Whatever be the chances involved in such a suggestion, they depend upon the conception of life consistently maintained throughout this section of our book, and which comes to be of crowning importance at the last.

The influence of intelligence on the evolutionary process

For Maeterlinck, for those who are now studying the atom, with the hope of being able to tap its stores of power, and for the ordinary man living his ordinary life, living creatures are not merely mechanical toys, to which things happen. They can do things, by virtue of the desire, the purpose, the will to live, which animates them. They are limited, conditioned, balked by the laws of matter, by the "cussedness" of external things and by their own bodies, for too often, "though the spirit is willing, the flesh is weak". Nevertheless, the directive power of the spirit remains. For the vitalist, this is the central fact of life, which he sees to be mind essentially; or, as Bergson puts it, "of the psychological order".

Some years ago, before the appearance of Bergson's great book, the present writer raised his voice in protest against the purely mechanical view of the future of life upon our planet. Neither in Herbert Spencer's "First Principles", nor in the physicists' theory of entropy, it was argued, was sufficient allowance made for "the influence of intelligence upon the evolutionary process"; and that "we will do well, in predicting the future of matter and motion, not to deem impotent the factor of mind".

But this protest means more today than was then realized, for Bergson has taught us to recognize mind in all life, and not merely in the life of man where mind is most perfected. We are therefore simply forbidden to infer the future of life from what we consider we know of the laws of matter and motion. If those laws make life as a by-product, then to investigate physical processes and to define their cosmic trend will indeed be to define the destiny of life. Let the students of cosmical physics say what is happening, and we can define the fate of living things. But if life is mind, and is not an "epi-phenomenon", or by-product of the changes in matter and energy, these predictions will be insecure. If we attempt to make such predictions about any individual creature, it defeats us.

According to the laws of matter and of motion, it should come to such and such consequences, but nothing of the sort happens, for the living creature, while we are calculating, makes up its mind (which we had not noticed) to do what it wants, and avoids the imminent fate which would have overtaken any not-living collection of matter and energy in similar circumstances. Now, if the physicists cannot accurately predict the fate of any living individual, because of the existence of a directive factor which they cannot measure, certainly they cannot predict the fate of life at large. In the last chapter we saw that man, as the most intelligent form of life, is already taking over the control of all the life of his planet. He exterminates, he breeds new types, he establishes new environmental conditions to which old types have to adapt themselves, he maintains "preserves" where old forms may persist unmodified.

We cannot admit that the cooling of the sun must necessarily put a term to this process. We see that there are sources of energy nearer at hand, not infinite, yet almost unlimited, which man may very soon learn how to employ. Many physicists and astronomers are even uncertain how far the doctrine of the dissipation of energy is sound; and it may be that, just as, according to the law of the conservation of energy, no energy is ever destroyed, so no energy is ever finally reduced to the somewhat mystical state described by the physicists, in which, though intact as energy, it is inert.

It is not the truly scientific but the unscientific man who sets limits to the possibilities of knowledge. Things asserted impossible to be done or known have over and over again been done and known. Perhaps the mind which is in all life, and above all in man, is part of the Prime Mover of all things. These things are too high for man's searching and thought to decide. Let us beware of finality, or of too great a confidence in the tentative conclusions of science.

Science is very young and small, and Truth is very old and great. Many of the most confident conclusions of the nineteenth century, not least in biology, have survived only to point a moral in the second decade of the twentieth. We see now that we know nothing absolutely certain as to the origin of life, and that, unless we assume rudimentary life to be omnipresent, we can never postulate a beginning for life as we know it.

The mistake of regarding living creatures as automata

We see now that the origin of species by natural selection was a theory of the destruction of species by natural rejection, and that the origin of new forms is as mysterious as the origin of the old ones from which they spring. We see now that the expedient of regarding all living creatures as automata is inefficient, because they persist in behaving as beings that have will and purpose; so that, the more we insist upon regarding them as machines, the more certainly we miss the very facts which make them alive, and on account of which we study them.

Such are the chief gains of the twentieth century in the science of life, and we see that they are all negative; they amount to no more than a rejection of false or partial views which were taken for the whole truth a few decades ago. The origin of life, of species, of mind, is yet to be found out; the problem of explaining the occurrence of mind in living things, unless we recognize it to have been there in the first place, is seen to be insoluble. The attempt to solve it has led the acutest thinkers into the most grotesque assertions.

The presumption of setting limits to the powers of life

It is time to make a fresh start, trying to concentrate upon the essential facts of living things, which are the facts of behavior. The more we do so, the more we see that all living things behave, that a purpose, a will, an *élan*, a power of self-direction and self-expression, is their common character, and that to attempt to set limits to its powers would be presumption, when we remember their past achievements, and our incapacity to measure the Infinite and Eternal from which they proceed.

HEALTH IN CHILDHOOD

The Course of Care by which Children
Will Grow up Naturally Well and Strong

GENERAL PRINCIPLES AND SPECIAL HINTS

WITH every thing, but with living beings above all, beginnings matter immensely. The living creature has in it at any moment the whole of the individual and racial past. If we wish to secure its health we cannot begin too soon. A chapter must therefore be devoted, before this section closes, to the physical health of infancy and childhood, in the proven belief that attention to hygienic principles at these periods will be repaid at every subsequent stage of life.

In the United States the physical care of school children has already reached a great development. The work of the medical inspector at first was only to quarantine cases of acute infectious disease, segregate those exposed and close and disinfect the school if necessary. Later was instituted an examination of the eyes, ears, nose, throat and finally the teeth.

If we desire to maintain the health of a child, and if we cannot determine what child, of what ancestry, it shall be, we must at least begin with the care of its mother before its birth. Such a mother will regard herself as holy, as a veritable creatrix of life to come. A very few words suffice to define her duty at this period, for herself and her child. It is very necessary that she should be happy — as happy as possible. Especially during the last three months she must avoid every kind of strain, excitement, and unrest. Social "duties" and the like must be regarded as of no moment now. The expectant mother who takes proper care during the last three months will bear her child longer; and this means that its birth will be easier for her and its chances of life much raised. But physical idleness is not desirable. Gentle, regular daily walking exercise is most important for the proper health of the body and for the tone of the muscles, and for the obtaining of good sleep.

This last point is most important, and is urgently insisted upon by all modern obstetricians. We need hardly point out that the physical and psychical difference between such exercise and hard, prolonged, compulsory, manual labor is extreme, and that the one is as good as the other is bad for the expectant mother.

During the last few weeks she will attend carefully to the invaluable organs upon which her child's chances of life will largely depend; for we know, beyond dispute, that no perfect substitute for its mother's milk can be found. When the baby is born, its eyes will be immediately and thoroughly bathed and washed out. It needs no food as yet. Twenty-four hours may elapse; and during that period the baby should receive no sugar-and-water, nor any other absurd and irrelevant concoction without the sanction of nature. Thereafter, the child should be put to the breast; and if its mother can nurse it for many months to come it will make the best possible start in life.

No child is born rickety. There is no such thing as "congenital rickets," though the phrase has been used. Nature knows better than to feed a child on what produces rickets before it is born. Every case of rickets is an *acquired* disease of malnutrition, for which someone is responsible.

It may be the mother; or some dead "statesman" who forgot to have the nation's future mothers taught the elements of living when they were at school; but someone is certainly responsible. A mother should be encouraged to nurse her child herself, thus guaranteeing it against rickets — for a long time to come, at any rate. Her vital energies have toiled for it unceasingly, day and night, for many months. She may as well complete the task to which she has already given so much of her own life. If she wishes to prevent the child's fair promise from being blighted, her first duty is to nurse it herself. Most of the prize-winners of life were fed by their mothers when they were babies, and most of the babies that do not survive are *not* fed by their mothers. Nature has been at her task of saving babies a long time, and this is the way she has found best.

Doctors have tried everything they can invent for babies instead of their mothers' milk, and the conclusion of the whole matter is that mothers' milk is best. In France, where babies are scarce, and therefore precious, doctors tried feeding them with all sorts of things, but now they feed the mothers, and the wonderful chemistry of the mother's body does the rest.

Very often the mother thinks she cannot nurse the baby, and gives up trying, and unwise nurses and even doctors may help to dissuade her, and may say that the bottle will be better. In the end they turn out to be wrong, terribly wrong, over and over again. They should rather try to give the mother rest, peace of mind, and sensible food, with plenty of milky things.

Should the mother die, or there be conditions that make nursing impossible, substitute feeding must be resorted to. Wet-nursing is no longer popular in America, owing to the possibility of the nurse bringing disease into the household, to say nothing of domestic discord. Moreover, the child of the wet-nurse is likely to die as the result of neglect or unwise feeding. Should such a nurse seem essential, she should be subjected to the tuberculin test for tuberculosis and the Wasserman test for syphilis.

The grave lack of wisdom in unnecessarily early weaning

Of all the calamities that may occur to the infant during the first week or two, by far the most serious is that of unnecessary weaning. Far too often the influence of the doctor and the nurse is thrown upon the wrong side, and it is common to find the child weaned, to its serious injury, often mortal, simply because the expectant mother has not been taught how to care for the nipples, to draw them out if they are depressed, and to prevent them from cracking.

When the mother suffers from consumption, she certainly must not nurse her baby, for that would be dangerous both to her and to it. On the other hand, the relatively trivial malady called constipation is often a cause of unnecessary weaning. If the constipation persists, the milk is apt to be affected, to the child's detriment. On the other hand, if an aperient be given, the child receives a portion of the dose, and may be upset. Therefore, the simple rule is that, by a well-chosen diet and by proper exercise during the last few months of pregnancy, the expectant mother should prevent constipation; and then it will not be so difficult to keep things right afterwards.

But psychical causes, worry and excitement, are just as inimical to the proper establishment of nursing as is constipation itself.

The effect of mental causes in preventing the nursing of infants

Even among our domestic animals we find that alarm and excitement spoil the milk; and how much more is this likely to be true of so highly organized and sensitive a being as a woman. After childbirth many women are easily upset and depressed; and though a mother may put the best face on matters during the doctor's visit, he may find on inquiry, that she has been in tears over some comparative trifle. This very common tendency towards loss of mental equilibrium has a serious influence, in many cases, upon so delicate a function as the production of nutriment for the baby.

Of course, some mothers really cannot nurse their babies, and then they must ask a cow to help them. But this involves serious risks, which must be guarded against. Cleanliness is all-important, for the lack of it means the growth of millions of microbes in decayed milk, which is an admirable medium for their growth. In Manchester it was noted that the death curve of diarrhœa in infants corresponded closely to the prevalence of flies. Another study showed that the death-rate rose as the wages fell, which means more crowding of persons in small rooms. The death-rate for all ages rises with increased density of population, but the rise is four times greater for infants than for other ages.

The proper manner of feeding the baby after it has been weaned

A study of 844 breasted infants in Westminster (London) showed 84.8 per cent of them healthy, and that only 2.3 per cent died within one year. Of 140 bottle-fed babies 47.1 per cent were healthy and 12.1 per cent died in one year.

Though the right beginning for a baby is to be fed by its mother, there comes inevitably the time when the mother's milk no longer satisfies the baby, and it must have something more. It requires to be weaned, and very often indeed it suffers in the process, mostly because of the things we use to help it. No baby that has not completed its first year should be asked to digest any kind of starch. The baby does not have in its body the kind of digestive ferments which can digest starch, and therefore no food which contains starch is proper for an infant that is just being weaned. There is no starch in milk, but unfortunately mothers cannot be persuaded that milk is "solid nourishment," though the modern vogue of dry milk must have taught many.

The overwhelming value of milk as a food for children

The chief defect in the feeding of most children from weaning until they are far past their second year is that they do not get enough milk. Milk should remain the staple diet of a child for long after it is weaned. We should remember that many savage mothers do not wean their children until they are at least two years old, and that was probably the least period for maternal nursing in our species long ages ago. The one great staple food for childhood is milk, first, last, and all the time. And its own products, such as butter and cream, are its great allies.

Though milk contains no starch it has a valuable sugar in it; and we need not be afraid of letting young children have almost as much sugar as they feel inclined for, especially if it be the natural sugar in fruit. Sugar is a splendid fuel, with which young children can keep warm their small and therefore easily cooled bodies. Our grandparents were quite wrong in supposing that a child's fondness for sweet things was a sign of original sin. But we must certainly not use sugar to help us when we are weaning a baby, by putting it on a "comforter" or "pacifier," and letting the baby whom we are weaning suck that. No baby should have a "comforter" at all. It is a constant source of infection, not fit to put into a baby's mouth.

The discomforting effects of the so-called "comforter"

The proper name for this abomination is *discomforter*. Sucking at it makes the baby's saliva begin to run, and this soon interferes with its digestion. Even when the discomforter is solid, the baby usually manages to suck in a certain quantity of air; and this, together with the gas produced within the baby owing to its indigestion, naturally causes discomfort, crying, and flatulence.

Recently, also, the dental surgeons have shown that sucking at a dummy teat distorts the shape of the child's mouth, making the palate grow forward, and so ruining the natural shape of the jaws. Many of the ugly mouths and projecting upper lips we see in children and grown-up people are due to the "comforter." Precious little comfort it leaves behind it when the baby's mouth is distorted for life.

A "comforter", like a pipe, establishes a habitual need for itself, so that its discontinuance involves annoyance and irrit-

ability, which its resumption relieves. But this proves nothing in favor of the original employment of either. Mothers specially tend to use the comforter when babies are teething, but it is not worth while. The discomforter justifies its new name, by causing most, if not all, of the troubles which are supposed to be due to the teething, and for which the discomforter is supposed to be useful. The baby that is getting no starch, and that is getting plenty of clean milk, will cut its teeth with little trouble, or none at all. The bad reputation of teething, a perfectly natural and normal process, is mainly due to the stupid way in which we have been content to mishandle babies, and especially their stomachs and their mouths.

The true and invariable cause of infant rickets

There is a great delusion to the effect that rickets is only a weakness of the bones, and that, so long as they are all right (or apparently all right), a child must be free from rickets. But, in fact, rickets is a constitutional disease, caused solely by unsuitable feeding, which shows itself in a host of ways, if we know how to look for them; and it has gone a very long way before it tells upon the external appearance of the bones. Many babies have straight limbs, perhaps with plenty of fat upon them, who are rickety nevertheless. In many cases there is an excess of fat, which cannot be properly burnt up by the disordered chemical economy of the child; and these cases often deceive all but the expert, who knows how to look for the crucial signs of malnutrition.

Only the expert need study these signs; for the rest of us, it is sufficient to know how their appearance may be prevented. An abundance of fresh milk, as we have seen, comes first, and then good bread, not too starchy, but made from a good flour with the germ of the wheat-grain in it. Unfortunately, when we praise milk and its derivatives and applications, many mothers are inclined to think of pap, bread-and-milk and so forth, with nothing that can possibly need chewing. Then they are sorry that their children's teeth are so poor. Of course they are poor if the child's growing body was never given to understand that teeth and chewing were to be expected of it. That is the great mistake which has been made for many years past in the feeding of young children, and then we find, of course, that nine out of ten of the nation's primary public school-children need the dentist badly, and at once.

A child's teeth are meant to be used. Their use helps the blood to flow freely in the blood-vessels of the jaws, and so to make them and the teeth they bear as strong and well formed as they should be. Very few people know how much this means for beauty in later life. Children must have good, firm rusks, or toast, or crust of bread. Every doctor who has studied the subject is enraged when he sees the crusts cut away from children's bread. The crusts are richer than the crumb in nourishment, and they are invaluable as providing exercise for the teeth and jaws. Not only does this exercise help the teeth and jaws themselves, but it starts the digestion of the food in the proper way by getting plenty of saliva mixed with it before it is swallowed.

The regulation of children's health by food possible without medicine

Some of the modern wheat-foods are excellent for children, both in themselves and because they need chewing. If our children are to have good teeth, properly developed jaws, and healthy mouths, we must stop feeding them on pap. And though a young child's teeth are only temporary, the better they are treated the more likely are their successors to be what are still kindly described as the "permanent teeth".

We have already seen that constipation in the mother is a source of danger to the nursling. Constipation in the child itself is to be regarded most seriously. A tiny infant should be most scrupulously observed in this respect, in which nearly all infants and young children give trouble at some time or other. When weaning has been accomplished, and we are doing our best to provide the baby with a suitable diet, which very likely comprises a boiled or otherwise sterilized milk, we often find that it becomes consti-

pated. Cows' milk is a constipating thing, especially if it has been boiled. The fat or cream in it is the constituent which helps to keep the bowels active, and hence cream and butter have a special value for young children beyond that involved in their high proportion of nutrient material.

The child must not be allowed to be constipated. The next thing will be that it is poisoned, and the opposite of constipation will follow, in the attempt of nature to get rid of the poisons which the constipation produced. But when a child is constipated we follow our usual rule with adults as with children, and begin to think of drugs first. That is where we are wrong. We should think of drugs last; and if we have done any good thinking before that we shall seldom reach them at all.

The high value of fruit as an element in diet

It is the diet that was wrong, and the diet must be attended to. A little more cream, for instance, may make all the difference.

Elsewhere in this section we have seen how valuable a part fruit may play in the dietary of the adult. But fruit is even more important for children. We all know how useful "fruit salts" may be, but do we all know how useful the salts in fruit may be? We still fancy that fruit is a luxury for children, presumably, because it is rather expensive, and because they are so fond of it. But fruit is a necessity in some form or other.

Orange-juice, lemon-juice, grapes, apples, prunes, figs, are all splendid things for children of all ages, to say nothing of grown-up people. Especially is this true of children who are being fed on boiled, sterilized, preserved, condensed or dry milk. Often a teaspoonful of orange-juice twice or three times a day has saved the life of a tiny infant, which was dying on some preserved artificial diet, just as Arctic explorers used to die of scurvy before the use of lime-juice made the discovery of both poles possible. The pathologists have not explained how it is that lime, lemon or orange-juice will cure or avert scurvy, whether in the adult or in "infantile scurvy", but the fact is unquestionable.

The unvitiated appetite of children a trustworthy guide

People who have made the experiment know that children who are allowed fruit, and even cake and sweets, freely do not exceed and make themselves ill. The trouble is that, thinking ourselves so clever, we usually deprive children of these things, and then, of course, they take too much when they do get the chance, and make themselves ill. We should trust children's appetites far more than we do. Then we should have to give them medicine very seldom indeed, and only as a last resort.

A healthy child of twelve needs nearly as much food as an adult and of as great a variety. Milk or cocoa and water are the proper drinks, not tea nor coffee. Plain food, without rich pastry or puddings, hot breads, etc., must be the dietary, and the amount required will depend on the weight of the child; for example a child of three, weighing thirty pounds will need 980 calories each day; one of five weighing 40 pounds, 1200; one of fifteen weighing 100 pounds, 2000.

As for meat, which many very young children dislike, or like very little of, they are right — that is to say, nature is right, and we are wrong. Which is, of course, not so surprising, when we come to think of it. On the other hand, beef-teas and meat preparations have their uses in many cases, and often help the appetite and the digestion of ailing or weakly children. They are to be looked upon not so much as foods in themselves as aids to the absorption and utilization of other foods.

Hints as to the sensible clothing of children

The feeding of infancy and childhood is of transcendent importance, but there are many other factors of health which we should consider. In matters of clothing, the "golden mean", which Aristotle commended more than two thousand years ago, is still often ignored. Some mothers believe in the "hardening" system, which has frequently justified its name by achieving the stiffness of death. They send out their children inadequately clothed, forgetting

how small a child's body is, how easily cooled, and how ready, in that condition, to harbor the microbes of bronchitis and pneumonia. Fashion and appearances play a ridiculous part in this connection. On one and the same cold morning in December you may see children in almost any public park of whom one is quite bare-kneed, and wears nothing but thin socks, while another has warm stockings, plus gaiters, which cover the entire leg and knee. Both extremes can scarcely be right.

It is well known that the knee-joint, the largest and most complicated in the body, is specially liable to the attacks of the tubercle bacillus. The physiologist — who knows how exposed the joint is, how incapable of producing heat on its own account, and how dependent upon an ample blood supply for the purpose of keeping up its temperature — cannot believe that the exposure of young children's knees to the cold winds of winter is a safe or rational proceeding. In general, it is a sound rule *not to chill children*, or any parts of their bodies.

The need for the open air in defiance of the weather

But it is no less sound a rule not to coddle them; and undoubtedly the "hardening school" stands for a very necessary protest against the view that children must be choked with woolen comforters and chest-protectors, and kept indoors whenever it is raining. The inevitable result of these procedures is to lower, instead of educating, the child's powers of resistance; and some day, when it is exposed to no particular degree of vital strain, it will succumb. Children should not be chilled, but neither should they be coddled.

The best rule is to provide them with abundance of clean, warm, absorbent, *loose* clothing, and then let them take the weather as it comes. For it is vitally important that children should get exercise, which they need far more than *temperately living* adults do; and the exercise which is not conducted in the open air is little better than a farce. All the distinctions between open air and mere fresh but confined air, to which attention was drawn in an early chapter of this section, are valid, even more for children than for adults. Man is not a mole, but an open-air animal; his young require exercise in the open air, of which all imitations are to be refused.

The open air as a preventive against adenoids

The properly clad child, with stout and entire soles to its boots or shoes, with hands and feet warm, and accustomed to play about in the open air in practically all weathers whatsoever, is the child least likely to catch cold, or any of the various forms of lung-infection. Not being subject to colds in early life, partly because it does not spend most of its time in a dust-laden atmosphere, this is the child that is least likely, so far as we know, to develop adenoids. It will be a nose-breather, and nose-breathers need concern themselves very little about the weather, for they carry their protective filter and air-warmer with them wherever they go. Already, in this section, reference has been made to the importance of nose-breathing, and the grave consequences of its chief obstacle, which is the presence of adenoids of the so-called "central" variety. The so-called "lateral" adenoids do not interfere with breathing directly, but they prejudice the hearing, and greatly increase the risk of infection reaching the middle ear from the throat, and perhaps doing irreparable harm to the drum.

The grave effects of adenoids, and some of their causes

An English authority on the subject, Dr. Macleod Yearsley argues that artificial feeding in infancy is a great cause of adenoids, because it involves unsuitable breathing on the part of the infant, unless very great care is taken; and it is indeed the fact that a great majority of adenoid cases occurs among the artificially fed, and a minimum in countries where normal maternal feeding is common. His conclusion is as follows: "Hence, in badly conducted artificial feeding, and in the use (or rather abuse, for it has no use) of the pernicious and abominable 'comforter', there is a fruitful factor in the occurrence of adenoids."

The need of guarding in infancy against future deafness

As a devoted student and champion of the deaf child, Dr. Yearsley should be listened to when he describes the early and neglected origin of the great number of those cases of deafness upon which quacks everywhere thrive. Here is what he says; and the parent who is not deaf to the voice of knowledge may save a child from a great disaster in years to come by listening now.

"It cannot be too vigorously stated, or too constantly reiterated, that chronic deafness in the prime of adult life depends, in the vast majority of cases, upon slow and progressive alterations, long unsuspected, because so insidious, in the middle ear. The fact that much of our normal auditory acuity is not required in everyday urban life makes this slow progress the more dangerous, for, so long as a conversation can be followed, or amusements enjoyed, the trouble passes unchallenged, and it is often not until hearing in one ear is nearly gone, and that of the other begins to go, that the patient awakens to his defect. It is in the course of the first years of life that the auditory apparatus is most exposed to inflammatory changes, and it is then that the foundations of chronic catarrhal deafness are laid down in the delicate middle ear, to develop insidiously and to overtake the victim somewhere about the full activity of the period comprised between the twenty-fifth and thirty-fifth years."

Deformities that come to children through undue strain

The limbs of a young child are possessed of what is, in large measure, a merely cartilaginous or gristly skeleton. They must not be exposed to too much strain. We constantly see small children who are allowed to go about on legs which are visibly buckling under the strain. This happens not least with heavy children, where the superfluity of fat and the special weakness of the bones are both due to the familiar cause, rickets. Of course, it is a great cruelty and injustice to a child to bend its limbs in this fashion, even though surgery might later straighten them. The simple ways of ensuring that a child grows up neither bow-legged nor knock-kneed are two. First, no young child should be allowed to remain on its legs too long at a time; the proper and natural exercise for childhood is rapid alternation of "spurts" and rest. Second, by attending to the diet of the child we can prevent that constitutional state of malnutrition which makes the young bones easy victims of undue pressure from above.

Not much less familiar is the deformity of the spinal column due to strain and neglect, and, in some cases, to unsuitable positions when reading and writing. These conditions are a source of income to doctors and masseurs and physical culture experts, for they are extremely intractable, and very likely to recur once they have established themselves, but they are easily preventable by parents who prefer to follow the almost costless and wholly common-sense injunctions of the present chapter. The child that is expected to use its limbs as it will, to hop and skip and jump in loose, warm clothing, in every kind of weather, and that is not expected to use its naturally long-sighted eyes at short range with lesson-books for several hours a day, will not suffer from curvature either of the spinal column or of the two columns upon which it is supported.

One of the recognized topics for discussion in regard to the hygiene of childhood is ventilation. Of course, a child's nursery and schoolroom should be airy and well ventilated. Of course, the bedroom window should be open at night. Certainly there should be as little dust as possible, and therefore as little as need be of the kind of hangings and floor-coverings from which dust is largely derived.

But our discussion on the subject would be out of touch with modern knowledge if we said anything to suggest that even the very best rooms are the right environment for a child that might be getting out into the open air. That point has been established for adults; and the experience of open-air schools, beginning with the famous Forest School at Charlottenburg, has established it still more amply for children.

Deep and prolonged sleep a cardinal necessity for children

Deep and prolonged slumber is a cardinal necessity for the health of childhood. Its importance cannot be overstated, or insisted upon too frequently. Half the good of the open air, the exercise, the liberty for which we plead during the child's waking life, is that these conduce to the right kind of sleep as nothing else can. If the child is uneasy in his sleep, suffers from bad dreams and night-terrors, the facts must be examined into. Very often the cause will be found in adenoids, which interfere with breathing, and thus produce, during sleep, the symptoms characteristic of partial asphyxiation. The old fallacy that the usefulness and efficiency of sleep can be measured by the clock must be carefully guarded against.

There is no doubt children sleep deeply, and are often not easily roused. We assume, therefore, that noises do not very much matter, in reason, provided that the child is not actually wakened. This is a serious error, which spoils the quality and therefore reduces the value of the sleep of many unlucky children. There are careful students of the conditions of nervous development who believe that many of the phenomena displayed by the city poor of this country are really due, perhaps above all, to the bad quality of the sleep which they obtained during childhood.

The noises of the night a menace to national health

The increasing nocturnal noise of our cities is a menace to national health, largely because it means that children do not get the quality of sleep they require, and to which they are entitled, for the proper development of the brain, and therefore of the body in general. This is a matter which has already received the attention of a number of cities, as, for instance, New York and London.

Lastly, it should be remembered, that the wilful public exposure of children to any form of infectious disease is a *crime*, against the child and against the public, in most states forbidden by law. The theory underlying such exposure, which was once a matter of daily practice, is that, since the child must catch the disease sooner or later, it may as well have it along with its brothers and sister, and get it over with. To this the reply is that children do not need to have these infectious diseases; and that, if we choose to protect children during their period of great susceptibility, the chances are high that they escape the disease altogether.

The fatal theory that children must catch childish diseases

Second, such diseases as measles and whooping-cough are terrible destroyers of child-life. They claim their scores of thousands of young victims every year; but the death-rate from these and similar diseases, such as scarlet fever, diminishes as the ages of the patients rise. Every year that passes a child is less likely to catch these diseases, and is stronger to fight them if caught. The law takes cognizance of contagious and infectious diseases as they menace the public health, for the protection of which health and quarantine laws are enacted under the broad authority of the police power of the state. Under this authority state boards of health are created and general statutes, delegating power to local boards in cities, passed. Violations of the sanitary code are usually made misdemeanors and punished by imprisonment or fines.

PRINTED IN THE U. S. A.